Fishery Data Series No. 94-13

Stock Assessment of Arctic Grayling in the Salcha, Chatanika, and Goodpaster Rivers During 1993

by

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STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE SALCHA, CHATANIKA, AND GOODPASTER RIVERS DURING 1993[1]

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ABSTRACT

Abundances and stock compositions of Arctic grayling *Thymallus arcticus* were estimated for portions of the Salcha, Chatanika, and Goodpaster rivers in 1993 using single-sample mark-recapture experiments. The Salcha River study area was from river kilometer 40 downstream to the Richardson Highway Bridge (river kilometer 3.2); the Chatanika River study area extended from 5 kilometers above the Elliott Highway Bridge downstream to approximately 24 kilometers above the Murphy Dome Road extension; and, the Goodpaster River study area was from river kilometer 52.3 downstream to river kilometer 2.7. Estimated abundance of Arctic grayling ≥ 150 millimeters fork length for the Salcha River study area was 15,950 fish (SE = 2,442) and for the Goodpaster River study area 10,841 fish (SE = 1,340). Estimated abundance of Arctic grayling ≥150 millimeters fork length for the Chatanika River study area was 11,766 fish (SE = 1,273) and for Arctic grayling ≥ 189 millimeters fork length was 9,506 fish (SE = 971; both estimates are given for the Chatanika River because there were no recaptures below 189 millimeters fork length). Estimated densities of Arctic grayling ≥ 150 millimeters fork length within the Salcha River study area was 433 fish per kilometer. Estimated densities, however, varied between sections of the Salcha River study area (365 fish per kilometer in the upper section and 493 fish per kilometer in the lower section). Estimated densities of Arctic grayling ≥ 150 millimeters fork length within the Chatanika River study area was 150 fish per kilometer. Estimated densities, however, varied between sections of the Chatanika River study area (252 fish per kilometer in the upper section and 89 fish per kilometer in the lower section). Densities of Arctic grayling ≥ 150 millimeters fork length in the Goodpaster River were similar throughout the study area (217 fish per kilometer). The proportion of age-3 fish were: 0.47 (SE = 0.02) in the Salcha River study area; 0.21 (SE = 0.02) in the Chatanika River study area, and; 0.45 (SE = 0.02) in the Goodpaster River study area. The proportion of Arctic grayling from 150 to 270 millimeters fork length within the Salcha River study area was 0.81 (SE = 0.01), within the Chatanika River study area 0.51 (SE = 0.03), and within the Goodpaster River study area 0.91 (SE = 0.01). For comparison of abundance between years: abundance of Arctic grayling ≥ 200 millimeters fork length within the Salcha River study area was 7,706 fish (SE = 2,555) in 1992 and 8,927 fish (SE = 1,518) in 1993; abundance of Arctic grayling ≥ 150 millimeters fork length within a similar section of the Chatanika River (from above the Elliott Highway Bridge downstream approximately 64 kilometers) was 11,712 fish (SE = 1,429) in 1992 and 10,315 fish (SE = 1,251) in 1993; and, abundance of Arctic grayling ≥ 150 millimeters fork length within the Goodpaster River study area was 6,886 fish (SE = 809) in 1992 and 10,841 fish (SE = 1340) in 1993.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, abundance, population abundance, age composition, size composition, length composition, electrofishing, movements, Salcha River, Chatanika River, Goodpaster River, Tanana River drainage.

INTRODUCTION

Mills (1993) estimated that sport fishermen harvested 14,983 Arctic grayling *Thymallus arcticus* within the Tanana River drainage (Figure 1) of interior Alaska in 1992. In addition to the harvest, it was estimated that 100,650 Arctic grayling were caught and released. Two of the largest Arctic grayling fisheries within the Tanana River drainage take place in the Salcha River (12% of the harvest) and Chatanika River (11% of the harvest). The Goodpaster River supports a smaller, but nonetheless important, Arctic grayling fishery (5% of the drainage harvest). The Goodpaster River Arctic grayling stock is important because Arctic grayling from the Goodpaster River are harvested in at least five fisheries including the Delta Clearwater and Richardson Clearwater rivers (Ridder 1991). The Goodpaster, Delta Clearwater, and Richardson Clearwater rivers account for 13% of Arctic grayling harvested within the Tanana River drainage. Although these fisheries are large, very little is known about the population dynamics of Arctic grayling in these rivers.

As noted by Ridder et al. (1993), Arctic grayling fisheries in the Salcha, Chatanika, and Goodpaster rivers have some distinct differences that affect the characteristics of each stock. Some of these differences include hydrologic characteristics, methods of access, and history of the recreational fishery. All three rivers are rapid run-off streams. However, there is variation in gradient, water depth, channelization, and bottom structure among these rivers. Access to these rivers for recreational fishing is also variable; the Goodpaster River is less accessible than either the Salcha or Chatanika rivers, which both have roadside access. The primary recreational fish targeted in the Salcha and Goodpaster rivers are Arctic grayling. In the Chatanika River, however, this distinction is shared with whitefish (least cisco *Coregonus sardinella* and humpback whitefish *Coregonus pidschian*). These factors, as well as others, influence the quality of each fishery.

A goal of this study is to provide stock assessment data on the Salcha, Chatanika, and Goodpaster rivers to assist area fishery managers in stock management decisions. Precise knowledge of fishery characteristics and population dynamics of Arctic grayling in these streams is important to fishery managers. The present report is the fifth in a series of reports, initiated in 1989, that summarize at minimum age-3 and older (greater than 149 mm fork length) Arctic grayling abundance and composition characteristics of the Salcha, Chatanika, and Goodpaster rivers.

The research objectives for 1993 were to:

1) estimate abundance of Arctic grayling greater than 149 mm fork length (FL) in the lower 36.8 km of the Salcha River;

2) estimate abundance of Arctic grayling greater than 149 mm (FL) in a 105-km section of the Chatanika River, beginning 5 km above the Elliott Highway Bridge downstream to the Murphy Dome Road Extension;

3) estimate abundance of Arctic grayling greater than 149 mm (FL) in the lower 50.0 km of the Goodpaster River;

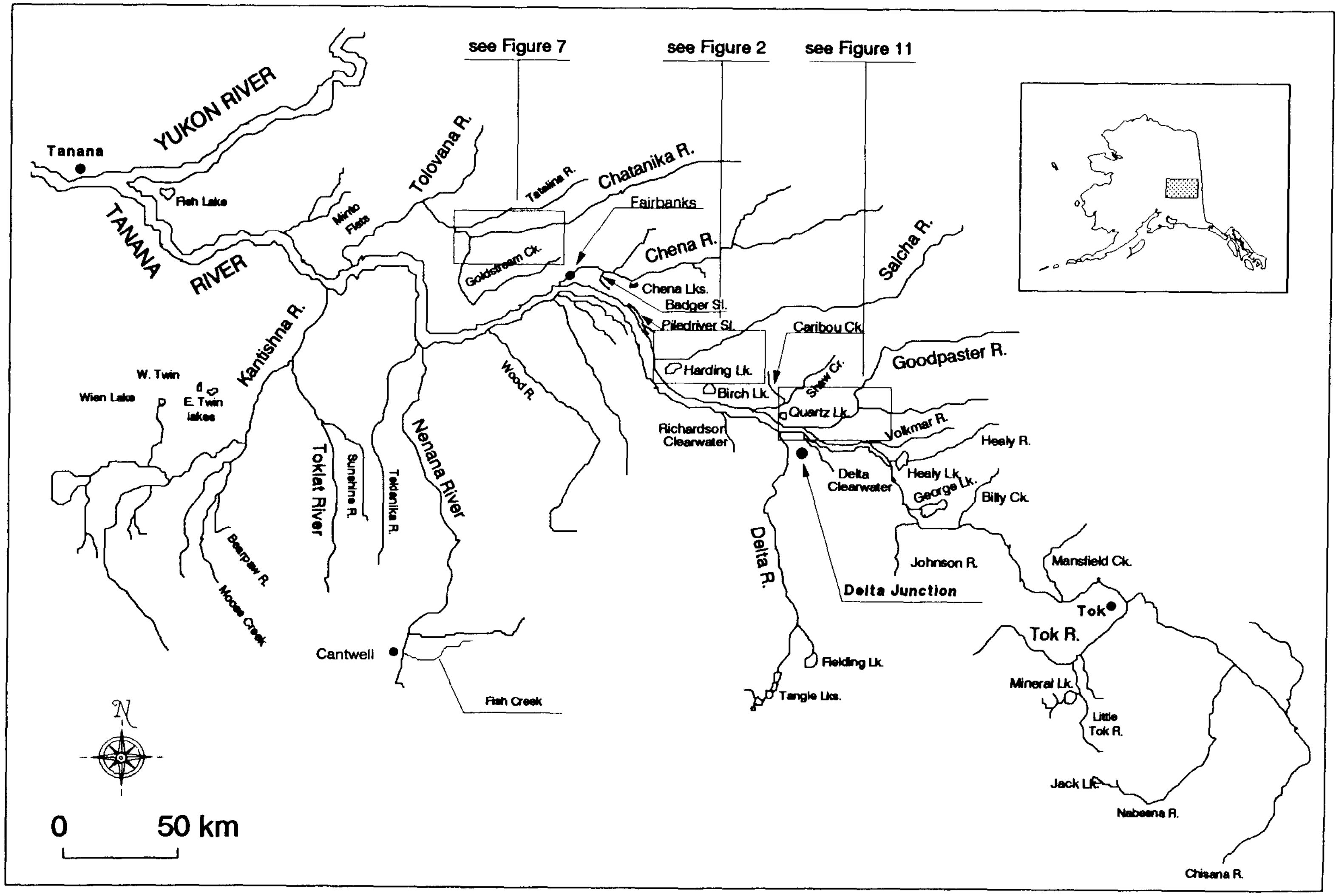

Figure 1. Tanana River drainage.

4) estimate age composition of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers; and,

5) estimate length composition of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers.

In addition, historical stock-assessment data summaries are presented for the Salcha (Appendix A), Chatanika (Appendix B), and Goodpaster (Appendix C) rivers (adapted from Ridder et al. 1993). Although not always directly comparable, these summaries provide an historical context that managers may use to evaluate the results of the present investigation.

GENERAL METHODS

Specific methodologies have been developed to estimate abundance of Arctic grayling in rivers of interior Alaska. Sampling schemes have evolved from multiple-sample mark-recapture experiments in short index areas (Van Hulle 1968) to single-sample experiments in relatively longer study areas (Clark and Ridder 1987). This change to longer study areas was made possible, in part, because jet propelled riverboats enabled investigators to sample longer contiguous sections of rivers that were previously not sampled because of shallow runs. In addition, the use of boat mounted electrofishing techniques have provided a means to capture a greater number of fish and cover longer stretches of river in less time and with less effort. As with other sampling methods, electrofishing may be size selective (Reynolds 1983). Mark-recapture methodology, however, may be used to correct for length bias from sampling gear without sacrificing the success of the experiment (Appendices D2 and D4).

For these experiments, the study area of each river was > 36 km in length. The longer study areas, in general, minimize the proportion of fish that immigrate or emigrate during the experiment. The study area of each river was divided into three approximately equal sections to evaluate movement. To standardize effort each section was divided into several electrofishing runs (the distance covered during 20 minutes of active electrofishing; usually < 2.5 km).

Each aluminum electrofishing boat had a crew of three; two captured fish with dip nets and one piloted the boat. Each boat was equipped with a pulsed DC variable voltage pulsator (VVP; Coffelt Model VVP-15) powered by a 3,500 W single-phase gasoline generator. Anodes consisted of four 15 mm diameter steel cables (1.5 m long) arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the aluminum boat was utilized as the cathode. Settings on the VVP were standardized at 60 Hz and 50% duty cycle (duty cycle is the duration the electrical pulse is on during one cycle, expressed as a percent of the cycle). At a given voltage, amperage varied according to the conductivity, substrate, and water depth of the river. The boat operator, however, made every effort to keep the output constant to minimize fish injury and mortality. Voltage was adjusted at the VVP to keep the output at < 5 amperes as conditions changed.

To reduce bias, sampling was spread evenly down each river with equal effort throughout the study areas. Each sampling event started at the upstream boundary of the study area and continued in a downstream manner. During the marking events, two electrofishing boats simultaneously fished (one on each bank) in a downstream direction for a standard 20 minute run. During a run, as many Arctic grayling as possible were captured with dip nets and placed in a holding tub that was aerated with running water. During the recapture events, one electrofishing boat fished both banks of the river, each for a 20 minute run. At the end of each run fishing ceased; fish were sampled and released before continuing. Before release, the fork length of each captured fish was measured to the nearest mm, scales taken for ageing, a Floy FD-68 internal anchor tag attached (during the marking event only), and a fin clipped as a double mark. Run boundaries were either marked with flagging or a unique landmark was noted in field notes or on a topographic map.

For ageing, two scales were taken from each captured fish during the marking event of the Salcha and Goodpaster rivers and during the recapture event of the Chatanika River. All scales came from an area on the fish centered approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were placed on gum cards in the field and retained for future processing and reading. Impressions of the scales were made on triacetate film using a scale press (30 seconds at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli with the aid of a microfiche reader. Determination of age was performed only once for each readable set of scales and all scales were read by one reader.

All data pertaining to age, length, sampling induced mortality, tag identification numbers and colors, capture location (by run and river section), finclips, recapture status, and tag loss were recorded on mark-sense forms and electronically stored for analysis and archival (see listing of data files in Appendix E1).

<u>Estimation of Abundance</u>

Abundances of Arctic grayling ≥ 150 mm FL were estimated for the Salcha, Chatanika, and Goodpaster river study areas with single-sample mark-recapture methods (Seber 1982), which in these experiments assume:

1) the population is closed (no change in the number or composition of Arctic grayling in the population during the experiment);

2) all Arctic grayling have the same probability of capture during the marking event <u>or</u> the same probability of capture during the recapture event <u>or</u> marked and unmarked Arctic grayling mix randomly between the marking and recapture events;

3) marking of Arctic grayling does not affect their probability of capture in the recapture event;

4) Arctic grayling do not lose their mark between events; and,

5) all marked Arctic grayling are reported when recovered in the recapture event.

Assumption 1 was not tested directly, but examination of fish movement from one section to another was used to infer significant movement of fish out of, or into the study area. Mortality and growth, which may also contribute to the violation of assumption 1, were assumed to be negligible because of the short duration of the experiment within each river (approximately ten days from beginning to end).

Assumptions 2 and 3 were evaluated by a series of tests that were designed to detect unequal catchability and gear selectivity, which violate these two assumptions. These tests include a chi-square contingency table test that compares catchability by river section, inspection of movement, and two Kolmogorov-Smirnov two-sample tests that compare catchability by length. The results of these tests, in combination, determine the methods used to compensate for bias in the abundance estimation. Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

Specifically, the chi-square tests compared catchability among sections during the recapture event (the frequency of fish with marks to the frequency of fish without marks). Inspection of movement was an empirical comparison of fish with marks that moved from one section of the river to another section between events to fish with marks that stayed in the same section. Movement was determined significant if more than 10% of fish marked in one section were recaptured in another section. Using the results of these tests, Appendix D1 outlines the methodology used to determine stratification by area and choice of abundance estimators (Appendix D3). In cases when stratification by area was necessary, the dividing point of the strata was chosen as the point that resulted in the maximum difference in catchability between the strata. The maximum difference was determined as the greatest chi-square value from a series of chi-squared tests that compared the frequency of fish marked in each stratum to the frequency of fish recaptured in each stratum.

After evaluating equal catchability by river section, equal catchability by length was addressed for each stratum separately or for the complete study area when stratification by area was not necessary. Kolmogorov-Smirnov two-sample tests were used to compare: 1) the length frequency distributions of recaptured Arctic grayling with all Arctic grayling captured during the recapture event; and 2) the length frequency distributions of Arctic grayling captured during the marking event with those captured in the recapture event. Using the results of these tests, Appendix D2 outlines the methodology used to determine stratification by length and choice of abundance estimators (Appendix D3). In cases when stratification by length was necessary the fish were divided into two strata by length. The dividing point of the two strata was chosen as the point that resulted in the maximum difference in catchability between the two strata. The maximum difference was determined as the greatest chi-square value from a series of chi-squared tests that compared the frequency of marked fish not recaptured in each length stratum to the frequency of fish recaptured in each length stratum. The number of size classes used for chi-squared tests was restricted to two because further stratification reduced overall precision while gaining little additional accuracy.

Double marking allowed investigators to test assumption 4. Tag loss was noted when a fish was recovered with a specific fin clip but without a floy tag. In addition, floy tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds.

Violations of assumption 5 were minimized by a thorough examination of the fins of each fish for clips and the recording of fin clips and floy tag numbers whether the fish was believed to be a recaptured fish or not. In all cases, an experienced crew member handled the fish and angler returns were not used.

Estimation of Length and Age Compositions

Length and age compositions of Arctic grayling ≥ 150 mm were estimated for the study area of each river and adjusted for differential capture probability when necessary. The integrity of these composition estimates relies on the same assumptions as abundance estimates. Unequal movement by length or age and gear selectivity by length or age violate these assumptions. Methodology to compensate for bias from violation of these assumptions is outlined in Appendices D1, D2, and D4 for estimates of length composition. Age compositions were estimated from samples from the marking event of the Salcha and Goodpaster rivers; and from samples from the recapture event of the Chatanika River. There may be bias associated with the estimates of these age compositions for three reasons: 1) equal catchability by age was not directly tested (it may not be necessary to test because age and length are correlated); 2) all fish in a sample were not aged (fish that were aged were not randomly selected; scales from larger fish were likely less readable); and, 3) fish < 150 mm were not included regardless of age (this may include two or more of the lower age classes).

Length and age proportions were estimated for each river directly when no adjustments were necessary; for each section when there was differential catchability by river section; and for each length stratum when there was differential catchability by length. When differential catchability was detected and the methodology of Appendices D2 and D1 called for stratification by river section or length the proportions were weighted by the ratio of the stratum to total abundance and summed for composition estimates for the study area using the equations of Appendix D4.

SALCHA RIVER

Abundance and stock compositions of Arctic grayling were estimated within a 36.8-km portion of the Salcha River in 1993. The Salcha River study area extended from river kilometer 40 downstream to the Richardson Highway Bridge at river kilometer 3.2 (Figure 2). For comparison purposes, prior investigators estimated Arctic grayling abundance and stock composition within this same study area each year since 1989 (Clark and Ridder 1990; Clark et al. 1991; Fleming et al. 1992; Ridder et al. 1993). In addition, abundance of Arctic grayling was estimated from mark-recapture experiments near Redmond Creek in 1972 (Tack 1973); within 8 km upstream and downstream of the Trans-Alaska pipeline crossing in 1974 (Bendock 1974; Kramer 1975); near Flat Creek in 1985 (Holmes et al. 1986); and from the Trans-Alaska pipeline crossing to 16 km upstream in 1988 (Clark 1988; Appendix A2).

Study Area and Fishery Description

The Salcha River is a rapid run-off stream that flows south out of the Tanana Hills into the Tanana River (Figure 1). The river intersects the Parks

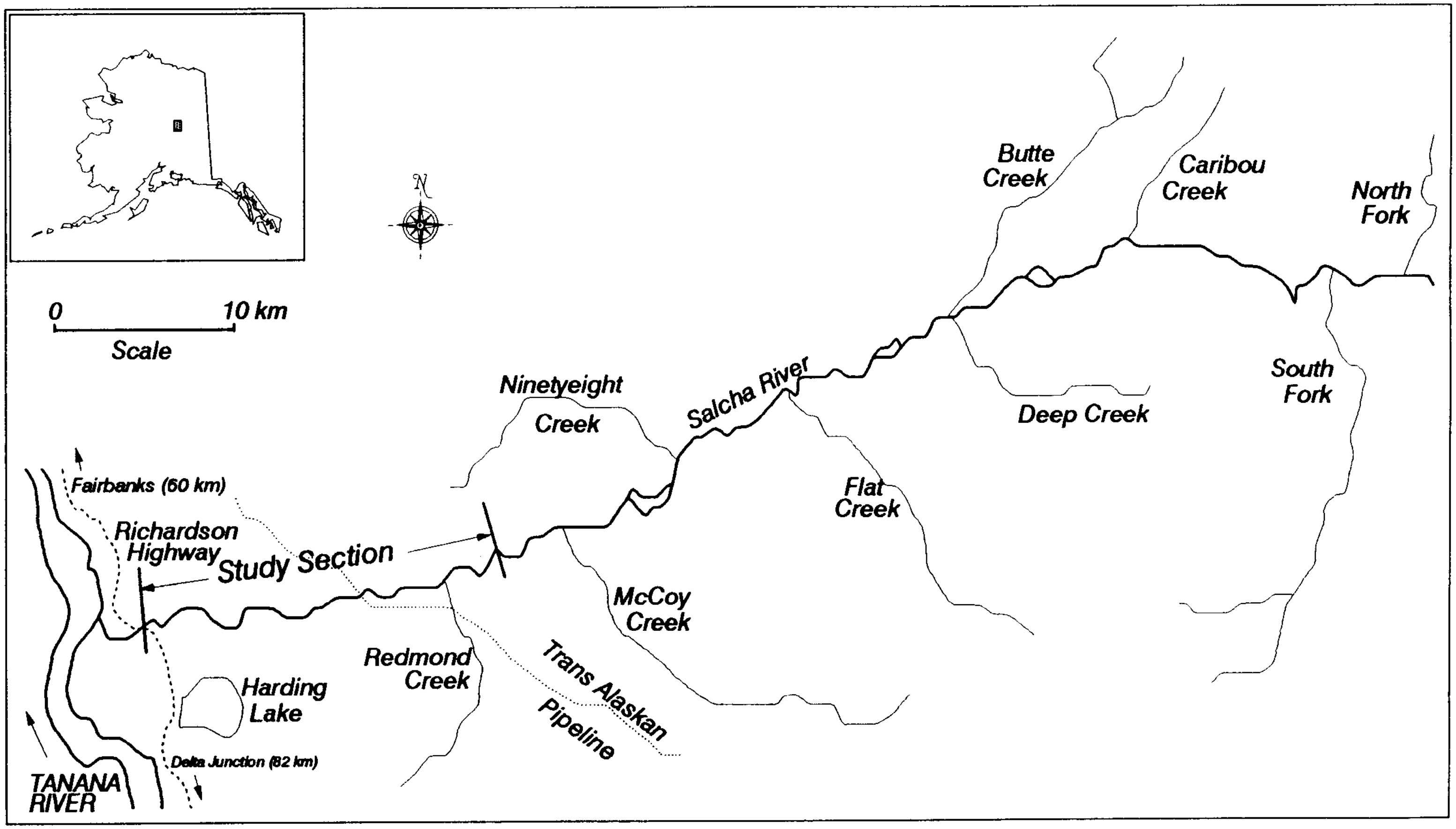

Figure 2. Salcha River drainage.

highway at milepost 348, approximately 70 km south of Fairbanks. The river is characterized by high gradient, long shallow runs, and exposed gravel bars. Holmes (1984) characterized the current study area as a single wide channel, average velocity of 0.8 m/s, and average gradient of 1.1 m/km. Average stream flow varies according to weather and spring runoff. For example, average stream flow in the study area from May through July has ranged from a low of 50.95 m^3/sec in 1980 to a high of 123.86 m^3/sec in 1984 (USGS 1976-1990).

The Salcha River fisheries are road accessible at the Richardson Highway Bridge at river kilometer 3.2. Access by car is limited to a 1.6-km section of river adjacent to the Salcha River State Recreation Area. A boat ramp, parking lot, picnic, and camping area are available at this state recreation area. Access to the river above the state recreation area is limited to river boat or airplane. Landing strips are located at Caribou Creek at river kilometer 96 and Pasco Creek at river kilometer 104.

The majority of recreational fishing in the Salcha River takes place in the lower 80 km of the river. More than 90% of all fish caught (released or kept) in the Salcha River in 1992 were Arctic grayling. In addition to Arctic grayling, fish caught in the Salcha River in 1992 included (from greatest to least number caught): northern pike *Esox lucius*, chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, whitefish *Family Coregonidae*, and burbot *Lota lota* (Mills 1993).

Prior to 1977, information collected from Salcha River Arctic grayling fishermen was sparse. Creel survey data for harvest rates were obtained during the summers of 1953 through 1958, 1963, and 1964. Harvest rates ranged from 0.48 Arctic grayling per hour to 1.09 Arctic grayling per hour from 1953 through 1958 (Warner 1959b); 0.67 Arctic grayling per hour in 1963; and 0.64 fish per hour in 1964 (Roguski and Winslow 1969). Harvest and effort surveys were conducted in 1968 and 1974. In 1968, Roguski and Winslow (1969) estimated 7,035 hours of effort and 7,048 Arctic grayling harvested for an estimated harvest rate of one fish per hour. In 1974, Kramer (1975) estimated 11,284 hours of effort and 4,728 Arctic grayling harvested.

Each year since 1977, as part of a statewide harvest survey Mills (1979-1993) estimated annual harvest and effort on the Salcha River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Salcha River was 5,754 fish, ranging from a high in 1984 of 13,305 and a low in 1992 of 1,592. Average effort on the Salcha River for all species of sport fish was 10,283 angler-days, ranging from a high in 1982 of 14,126 angler-days to a low in 1992 of 4,833 angler-days. In addition, each year since 1990, Mills (1991-1993) estimated annual fish caught (fish harvested plus fish caught and released) on the Salcha River (Table 2). The average annual catch of Arctic grayling on the Salcha River from 1990 through 1992 was 8,825 fish. In addition to the 1987 harvest data provided by Mills (1988), Baker (1988) estimated a catch rate of 0.66 (SE = 0.40) Arctic grayling harvested per angler-hour from May through August 1987.

Sport fishing regulations were restricted prior to the 1988 fishing season to protect the Salcha River Arctic grayling fishery from decline. These regulations were designed to:

Table 1. Arctic grayling harvest and effort on the Salcha, Chatanika, and Goodpaster rivers, 1977-1992 (Mills 1979-1993).

	Salcha River		Chatanika River		Goodpaster River	
Year	Harvest[a]	Effort[b]	Harvest	Effort	Harvest	Effort
1977	6,387	8,167	6,737	9,925	ND[c]	ND
1978	9,067	9,715	9,284	10,835	ND	ND
1979	5,980	14,788	6,121	4,853	ND	ND
1980	5,351	8,858	5,143	5,576	ND	ND
1981	3,983	8,090	3,808	4,691	ND	ND
1982	6,843	14,126	6,445	9,417	ND	ND
1983	9,640	11,802	9,766	10,757	3,021	1,989
1984	13,305	8,449	4,180	8,605	1,194	766
1985	5,826	13,109	7,404	10,231	2,757	2,844
1986	7,540	13,792	2,692	7,783	1,508	933
1987	4,762	10,576	5,619	11,065	1,702	3,061
1988[d]	2,383	7,494	8,640	11,642	1,273	1,037
1989[d]	5,721	9,704	6,934	12,210	1,964	1,930
1990[d]	1,992	9,783	4,237	11,801	760	2,083
1991[d]	1,688	11,242	2,642	8,085	636	786
1992[d]	1,592	4,833	1,751	6,775	766	1,430
Average	5,754	10,283	5,713	9,016	1,558	1,686

[a] Harvest is the estimated number of Arctic grayling caught and kept.
[b] Effort is the number of angler-days expended for all species of fish.
[c] ND = data not available.
[d] Special regulations were in effect on the Salcha River in 1988 through 1992. These special regulations were; catch and release Arctic grayling fishing from 1 April to the first Saturday in June; 12 inch (305 mm) minimum length limit; and, artificial lures or flies only.

Table 2. Arctic grayling catch and catch per angler-day on the Salcha, Chatanika, and Goodpaster rivers, 1990-1992 (Mills 1991-1993).

	Salcha River[a]		Chatanika River[b]		Goodpaster River[c]	
Year	Catch[d]	Catch/ Angler-Day[e]	Catch	Catch/ Angler-Day	Catch	Catch/ Angler-Day
1990	8,609	0.88	17,960	1.52	3,342	1.60
1991	9,600	0.85	12,830	1.59	905	1.15
1992	8,265	1.71	11,570	1.71	3,599	2.52
Average	8,825	1.02	14,120	1.59	2,615	1.81

[a] More than 90% of all fish caught from the Salcha River are Arctic grayling.
[b] More than 50% of all fish caught from the Chatanika River are Arctic grayling.
[c] More than 90% of all fish caught from the Goodpaster River are Arctic grayling.
[d] Catch is the estimated number of Arctic grayling caught (kept or released).
[e] Angler day is not specific to Arctic grayling fishing. This should be viewed as an index to compare effort between years within the same river but should not be viewed as a comparison among rivers because the proportion of effort toward Arctic grayling varies by river.

1) eliminate fishing for Arctic grayling during the spawning period (1 April to the first Saturday in June);

2) restrict methods of catching Arctic grayling to unbaited artificial lures;

3) restrict the harvest of Arctic grayling to fish 305 mm (12 in) or greater in total length (TL); and,

4) limit the harvest of Arctic grayling to five fish per day and five in possession.

Methods

The Salcha River marking event was completed from 7 June through 10 June 1993 and the recapture event from 14 June through 17 June 1993. A partial right pectoral finclip was used as a second mark during the marking event. In addition to the general methods used for the three rivers, the marking event for the Salcha River consisted of two complete passes through the study area instead of one. The purpose for the change from one marking pass to two marking passes was to ensure that the sample size of the marking event would be sufficient to meet accuracy and precision objectives. There was difficulty in meeting these objectives in 1991 with only one marking pass (Fleming et al. 1992).

Abundance Estimation:

Abundance of Arctic grayling ≥ 150 mm was estimated within the Salcha River study area using a modified Petersen estimator (Bailey 1951; 1952), as described by Seber (1982; Appendix D3). To reduce bias from unequal catchability by area, it was necessary to divide the study area into two area strata to estimate abundance; an upper stratum (river kilometer 40 downstream to river kilometer 22.9) and a lower stratum (river kilometer 22.9 downstream to river kilometer 3.2). In addition, to reduce bias from unequal catchability by length, it was necessary to divide the lower stratum into two length strata; 150 to 257 mm and greater than 257 mm.

Length and Age Compositions:

Length and age compositions for Arctic grayling ≥ 150 mm were estimated for each area stratum within the Salcha River study area. Proportions of fish by length and age were estimated directly for the upper stratum without length stratification (Appendix D4). However, for the lower stratum, the estimated proportion of fish by length and age was adjusted to reduce bias from unequal catchability by length (Appendix D4).

Results

Investigators handled 1,896 unique Arctic grayling (≥ 150 mm FL) during the Salcha River mark-recapture experiment. During the marking event, 1,294 Arctic grayling were tagged and released alive (661 during the first pass and 633 during the second pass of the marking event). During the recapture event, 668 Arctic grayling were examined for marks. Of these 668 fish, 602 were unique and 66 were recaptures from the marking event. Of the 66 recaptured fish, one (1.5% of tagged fish recaptured) lost its tag between events but was identified by the presence of a recent right pectoral finclip. During the marking event 29 Arctic grayling were killed or severely injured (1.5% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event 12 Arctic grayling were killed or severely injured (1.8% of fish handled during the recapture event). These fish were included in the experiment. Investigators identified 229 Arctic grayling (12.1% of unique fish handled) from prior mark-recapture experiments.

Abundance:

Unlike the Salcha River Arctic grayling abundance estimates of the previous two years, the present abundance estimate included fish from 150 mm to 199 mm FL. There was no need to truncate the data set this year at 200 mm FL because there were seven recaptured fish within the 150 mm to 199 mm FL range.

Recapture rates of Arctic grayling were significantly different among three approximately equal-length sections of the study area ($\chi^2 = 8.63$, 2 d.f., $P = 0.01$). The middle and lower sections, however, were similar ($\chi^2 = 1.00$, 1 d.f., $P = 0.32$). Furthermore, maximal difference in catchability was obtained by dividing the study area into two strata at river kilometer 21.6 ($\chi^2 = 8.89$, 1 d.f., $P < 0.01$). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) for the upper stratum was 0.06 and for the lower stratum 0.13 (Figure 3).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured indicated movement among sections (Table 3). Of recaptured Arctic grayling with known capture histories by location, seven of 65 (10.8%) moved from one section to another between events (marking location of one fish was not known). This was viewed as significant movement between sections because it was greater than 10%. It was possible that some fish moved out of the study area, however, the majority of movement between sections occurred from the lower section to the other two sections (five of seven fish). Movement between sections and a difference in catchability between sections of the study area indicated that none of the "or" conditions of assumption 2 were satisfied. Bias from different catchabilities between sections, however, was compensated for by following the methodology outlined in Appendix D1 (Case IV). The movement estimator described by Evenson (1988), the Darroch (1961) estimator, and the Bailey estimator resulted in similar estimates of abundance (1% or less difference); and the Bailey estimator yielded a smaller variance than the Darroch estimator. Therefore, the Bailey estimator was chosen to estimate abundance of Arctic grayling in each area stratum.

Within the upper stratum, there was no significant difference between the length distributions of fish marked and fish recaptured ($D = 0.28$, $P = 0.08$; Figure 4-A1). This result indicated that one of the "or" conditions of assumption 2 was satisfied. Specifically, at minimum there was no length selectivity during the recapture event. Therefore, an unstratified abundance estimate was used to estimate Arctic grayling abundance in the upper stratum (Appendix D2).

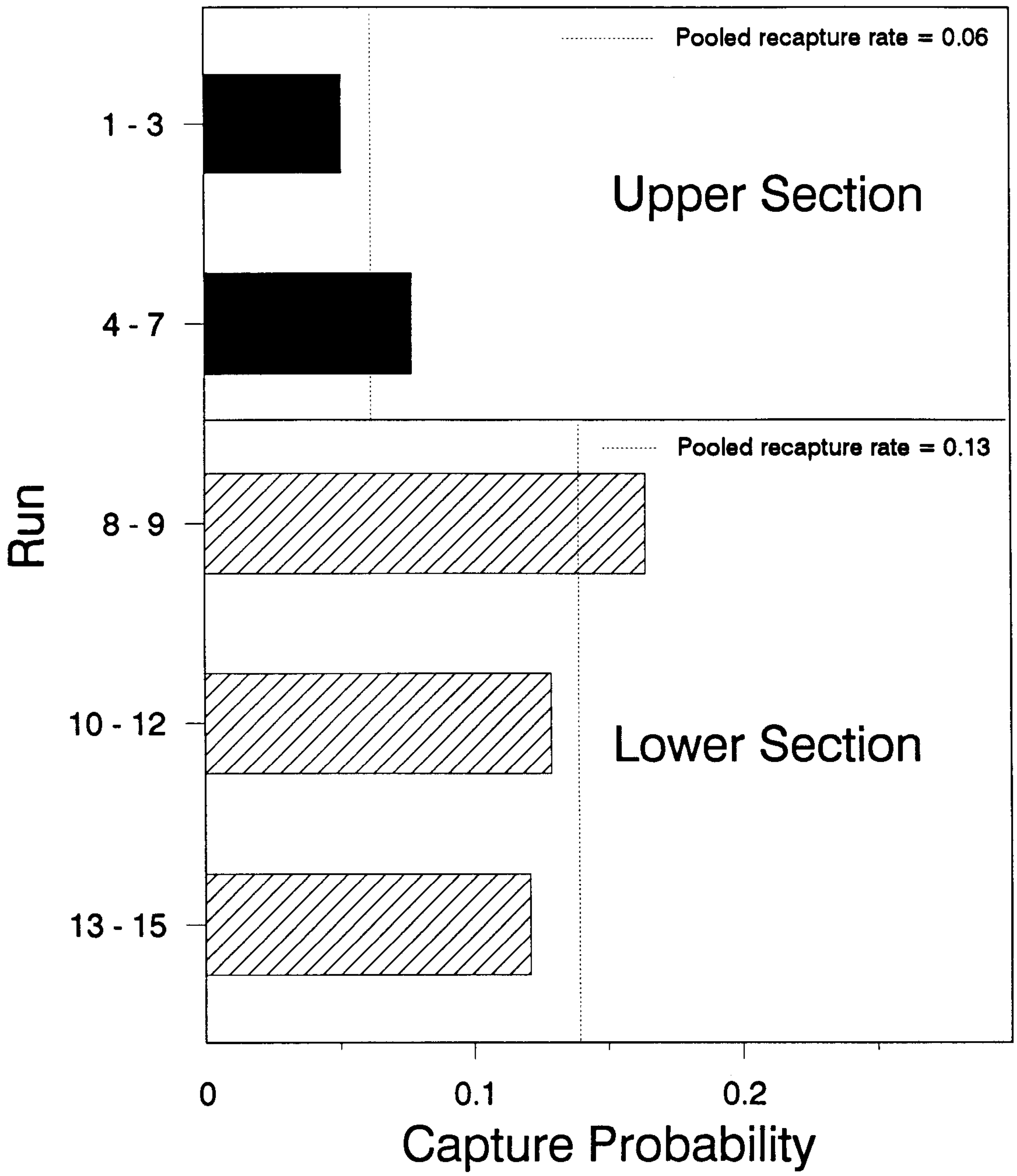

Figure 3. Estimated capture probabilities (number of fish marked in the first event and recaptured in the second event divided by the total number of fish captured in the second event) for Arctic grayling in two study sections of the lower Salcha River.

Table 3. Number of Arctic grayling recaptured[a] in a section and run[b] of the Salcha River summarized by the section and run in which the fish was originally marked. Fish along the diagonal did not move out of the run in which it was originally marked.

Mark		Number Recaptured															Number Moved (or Not Moved)	
		Section III					Section II					Section I					Between Sections	Between Runs
Section	Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
III	1	2															0 (2)	0 (2)
	2	1	0	1	1												0 (3)	3 (0)
	3			3	1												0 (4)	1 (3)
	4			1	2	1	1										1 (4)	3 (2)
	5				1	1											0 (2)	1 (1)
II	6						3										0 (3)	0 (3)
	7							1	1	1	2						0 (5)	4 (1)
	8								2	1	1						0 (4)	2 (2)
	9									6	2						0 (8)	2 (6)
	10										3	1					1 (3)	1 (3)
I	11										1	2		2		1	1 (5)	4 (2)
	12								1				2	3			1 (5)	4 (2)
	13							1			1	1		1		1	2 (3)	4 (1)
	14														0	3	0 (3)	3 (0)
	15				1									1	1	2	1 (4)	2 (3)
	Total	3	0	5	6	2	4	2	4	8	10	4	2	7	1	7	7 (58)	34 (31)

[a] This table does not include one marked fish that was recaptured without a tag. Movement could not be determined because the run it was marked in is not known.

[b] Locations are broken into river sections and run number (see Methods). A run is approximately 2.4 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 40.0 and run 15 ends at river km 3.2.

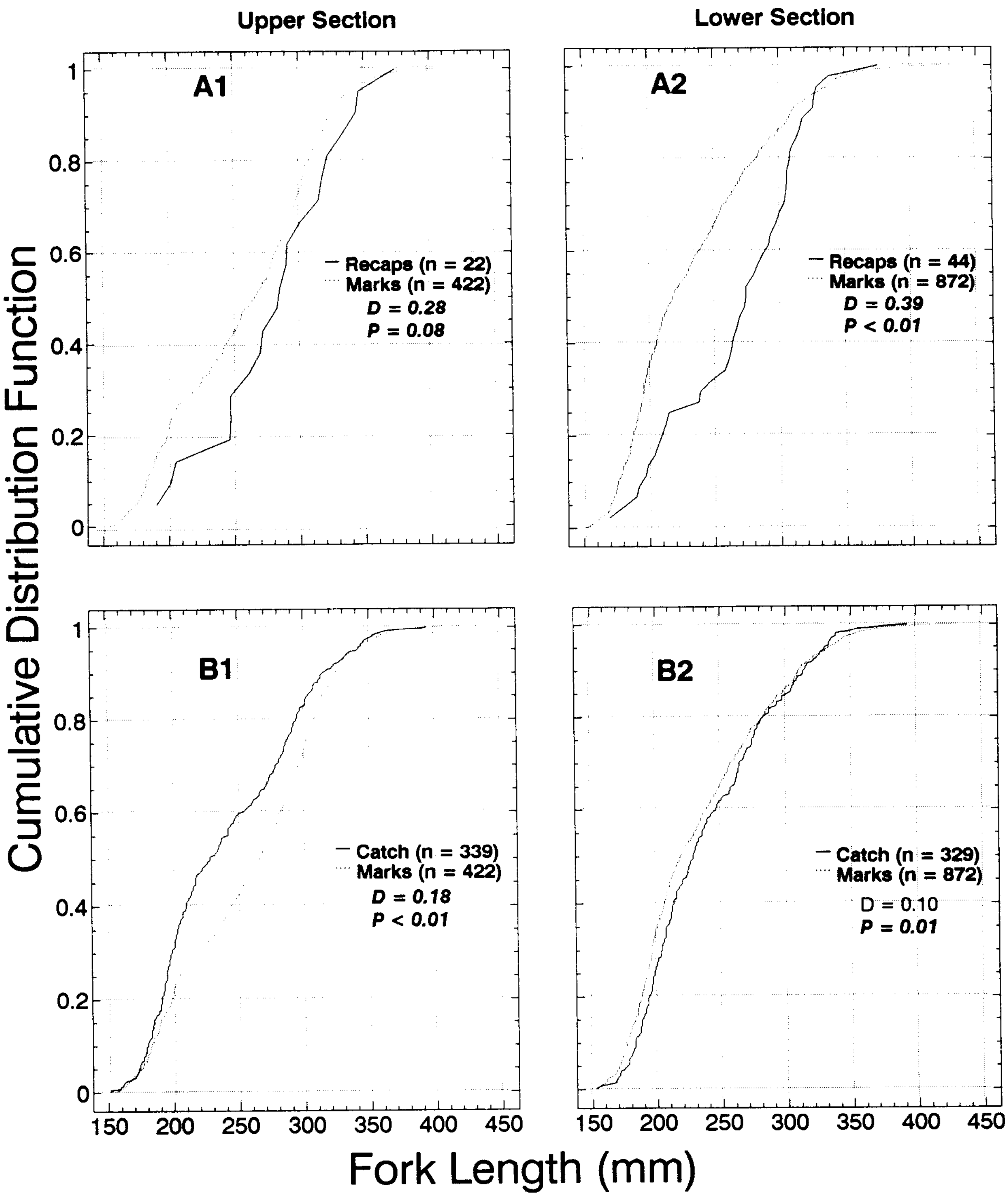

Figure 4. Cumulative distribution functions of fork lengths of Arctic grayling captured in two sections of the Salcha River. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

Within the lower stratum, however, there was a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.39$, $P < 0.01$; Figure 4-A2). There also was a significant difference between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.10$, $P = 0.01$; Figure 4-B2). This, along with no evidence of random mixing between events, indicated that none of the "or" conditions of assumption 2 were satisfied. Bias from different catchability by length, however, was compensated for by following the methodology outlined in Appendix D2 (Case IV). A length stratified abundance estimate was 52% different than an unstratified estimate, therefore, the length stratified estimate was used for the lower stratum. Maximal difference in catchability by length was obtained by dividing the fish into two length strata at 258 mm FL (small stratum = 150 mm to 257 mm FL and large stratum ≥ 258 mm; $\chi^2 = 32.59$, 1 d.f., $P < 0.01$).

Estimated abundance of Arctic grayling ≥ 150 mm FL within the Salcha River study area was 15,950 fish (SE = 2,442, CV = 15%; Table 4). Estimated densities of Arctic grayling ≥ 150 mm FL varied between sections of the Salcha River study area; 365 (SE = 67) fish per kilometer in the upper section and 493 (SE = 133) fish per kilometer in the lower section ($Z = 6.8$, $P < 0.01$).

Length and Age Compositions:

For the upper stratum of the Salcha River study area, there was not a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.28$, $P = 0.08$; Figure 4-A1), but there was a significant difference between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.18$, $P < 0.01$; Figure 4-B1). This indicated that there was no difference in catchability by length during the recapture event but there was a difference during the marking event within the upper stratum. Therefore, lengths from the recapture event were used to directly estimate length composition within the upper section.

For the lower stratum of the Salcha River study area, however, there was a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.39$, $P < 0.01$; Figure 4-A2), and between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.10$, $P = 0.01$; Figure 4-B2). This indicated bias from unequal catchability by length during both the marking and recapture events within the lower stratum. Methodology outlined in Appendix D2 was used to compensate for this bias. Length stratified and unstratified estimates of abundance were not similar. Therefore, lengths from the recapture event, stratified and adjusted for different catchability by length, were used to estimate length composition within the lower section.

Fork lengths of fish captured during the recapture event were used to estimate length composition of Arctic grayling ≥ 150 mm FL within both strata of the Salcha River study area. Fork lengths measured from 668 Arctic grayling (339 from the upper stratum and 329 from the lower stratum) ≥ 150 mm during the Salcha River recapture event ranged from 152 to 394 mm (mean = 240 mm,

Table 4. Estimated abundance (N), number of fish marked (M), number of fish examined for marks (C), number of fish recaptured with marks (R), and capture probabilities (R/C and R/M) of Arctic grayling (FL ≥ 150 mm) within the Salcha River study area, 7 through 17 June 1993, summarized by two study sections with different capture probabilities ($\chi^2 = 13.92$, 1 d.f., $P < 0.01$) and two length (FL) groups within the lower section with different capture probabilities ($\chi^2 = 32.59$, 1 d.f., $P < 0.01$).

Section[a]	Length Group[b]	Mark M	Catch C	Recap R	R/C	R/M	N[c]	SE[N]
Upper[d]	≥ 150 mm	422	339	22	0.06	0.05	6,238	1,230
Lower[e]	150-257 mm	612	213	14	0.07	0.02	8,731	2,105
	≥ 258 mm	260	116	30	0.26	0.11	981	149
	≥ 150 mm	872	329	44	0.13	0.05	9,712	2,110
Total	≥ 150 mm	1,294	668	66	0.10	0.05	15,950	2,442

[a] Sections were determined by dividing the study area at the point that maximized the difference between capture probabilities (R/C).

[b] Length groups were determined by dividing the groups at the length that maximized the difference between capture probabilities (R/M).

[c] The Bailey (1951;1952) estimator was used to estimate abundance of each section and length group; section and length group estimates were summed to estimate the total abundance of Arctic grayling within the study area.

[d] Boundaries for the upper section were approximately, river km 40 downstream to river km 25.6.

[e] Boundaries for the lower section were approximately, river km 25.6 downstream to river km 3.2.

SE = 2 mm). There was greater density of Arctic grayling ≥ 270 mm FL[1] within the upper stratum than within the lower stratum ($Z = 9.28$; $P < 0.01$). There was greater density of Arctic grayling < 270 mm FL within the lower stratum than within the upper stratum ($Z = 15.02$, $P < 0.01$). The estimated proportion of Arctic grayling ≥ 270 mm FL within the Salcha River study area was 0.19 (SE = 0.01; Figure 5). The largest Arctic grayling sampled from the Salcha River in 1993 was 430 mm FL, which was sampled during the second pass of the marking event.

Scales were only sampled during the first pass of the marking event of the Salcha River study. Therefore, ages from fish captured during the first pass of the marking event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within both area strata of the Salcha River study area. Ages were estimated from 536 of 661 Arctic grayling captured during the first pass of the marking event. Age classes ranged from age-1 to age-12. The age class with the largest proportion of Arctic grayling ≥ 150 mm FL within the Salcha River study area was age-3 (0.47, SE = 0.02; Table 5). A larger proportion of age-3 Arctic grayling was estimated within the lower stratum of the study area compared to the upper stratum ($Z = 40.39$, $P < 0.01$). Furthermore, a greater density of age-3 Arctic grayling within the lower stratum accounted for the absolute difference in Arctic grayling density between strata (Table 5). There may be some unknown bias associated with the Salcha River age composition estimates presented, given that age is correlated to length, because the Kolmogorov-Smirnov tests using length frequency distributions indicated that lengths from the recapture event should be used to estimate length composition for both the upper and lower strata (Appendix D2; Cases II and IV).

Discussion

Harvest of Arctic grayling from the Salcha River has decreased every year since 1989 (72% from 1989 to 1992). Effort on the Salcha River during the same period has been variable with a five year high in 1991. Harvest and effort, however, were both lower in 1992 than in any year since 1977 (Table 1). Some of this decline in harvest and effort may be a result of regulations, enacted during this same period, designed to protect the Salcha River Arctic grayling stock from decline. Restricted fishing regulations may have diverted some effort to catch-and-release fishing. There are no data, however, to support this hypothesis because there are no comparisons for catch-and-release information before the restricted regulations were put into effect (Table 2). It is believed, however, that catch-and-release fishing has generally increased over the last few years.

Although, overall estimated density of Arctic grayling ≥ 150 mm FL within the Salcha River study area increased in 1993 (Table 6), density varied by river section (Figure 5). Density of legal-length (≥ 270 mm FL) Arctic grayling was

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[1] Arctic grayling length classes divided at 270 mm FL is important for at least two reasons: 1) 270 mm FL = 305 mm TL = 12 in, which is the minimum length that Arctic grayling may legally be retained in the Salcha River creel and in specific areas of the Chatanika creel; and, 2) 270 mm FL is an approximate dividing point between mature and immature Arctic grayling within the Salcha, Chatanika, and Goodpaster rivers (Clark 1992).

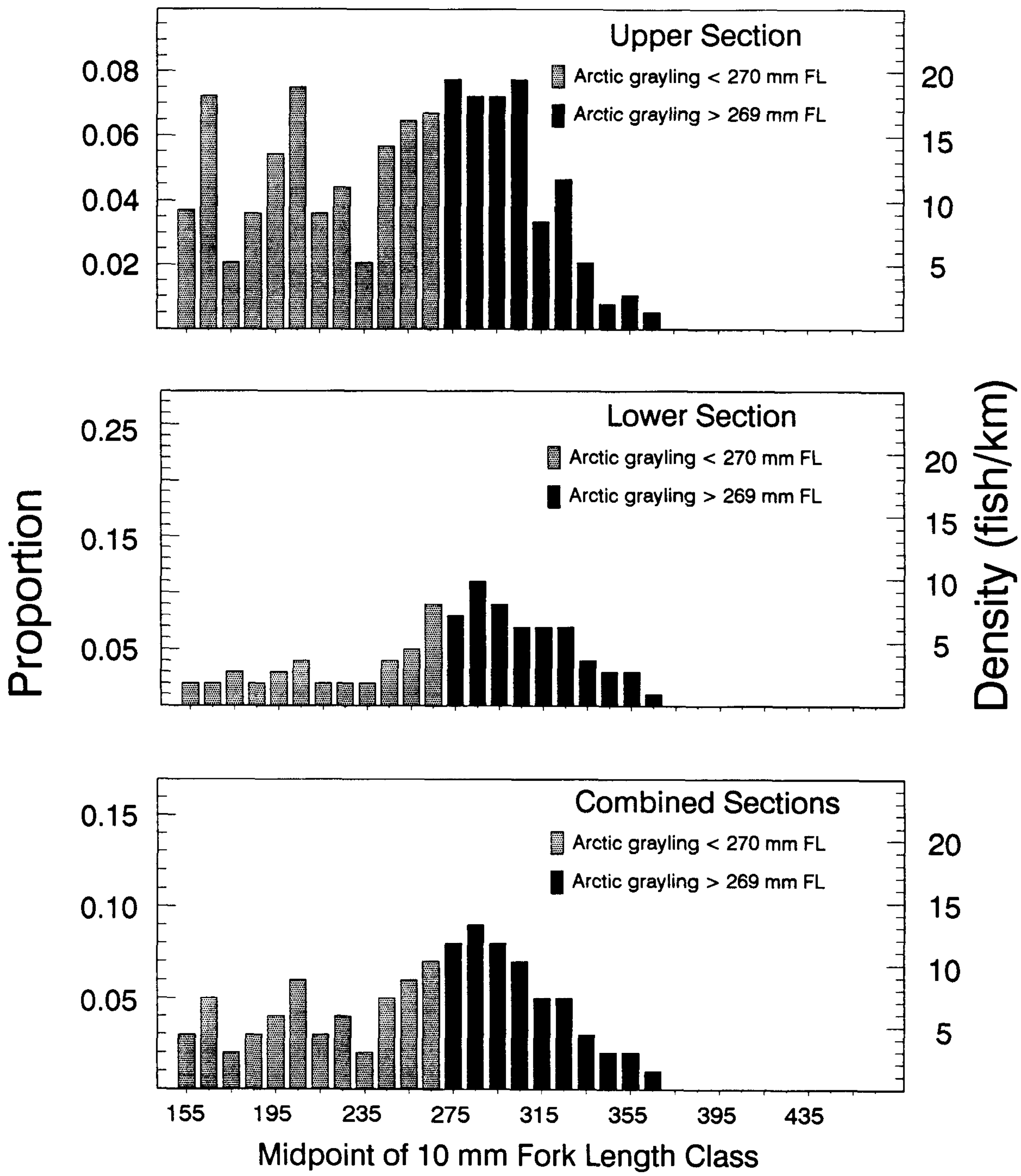

Figure 5. Estimated proportions and densities of Arctic grayling > 149 mm FL by 10 mm length increments within the upper, lower, and combined sections of the Salcha River study area during June 1993.

Table 5. Estimated abundance (N), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age and river section within the Salcha River study area (age samples from fish captured during the first marking event, 7 and 8 June, 1993).

Age Class	River Section											
	Upper[a]				Lower[b]				Combined			
	N	SE[N]	p	SE[p]	N	SE[N]	p	SE[p]	N	SE[N]	p	SE[p]
1	27	23	0.00	0.00	-	-	0.00	0.00	27	16	0.00	0.00
2	852	218	0.14	0.02	492	178	0.05	0.01	1,344	259	0.08	0.01
3	1,704	381	0.27	0.03	5,829	1,309	0.60	0.03	7,533	1,195	0.47	0.02
4	1,429	329	0.23	0.03	1,925	485	0.20	0.03	3,354	602	0.21	0.02
5	1,649	371	0.26	0.03	1,007	284	0.10	0.02	2,656	513	0.17	0.02
6	413	129	0.07	0.02	363	127	0.04	0.01	776	337	0.05	0.01
7	137	65	0.02	0.00	52	26	0.00	0.00	189	55	0.01	0.00
8	27	23	0.00	0.00	26	17	0.00	0.00	53	32	0.00	0.00
9	-	-	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00
10	-	-	0.00	0.00	9	8	0.00	0.00	9	7	0.00	0.00
11	-	-	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00
12	-	-	0.00	0.00	9	8	0.00	0.00	9	7	0.00	0.00
Totals	6,238	1,230	1.00	-	9,712	2,110	1.00	-	15,950	2,442	1.00	-

[a] Boundaries for the upper section were approximately, river km 40 downstream to river km 25.6.
[b] Boundaries for the lower section were approximately, river km 25.6 downstream to river km 3.2.
[c] Age composition for the lower section was adjusted for unequal catchability by size (Appendix D4).

Table 6. Estimates of density (number of fish/km) of Arctic grayling ≥ 150 mm FL within the Salcha, Chatanika, and Goodpaster rivers study areas from 1990 to 1993.

	Density and (SE)			
Study Area	1990	1991	1992	1993
Salcha River	157 (18)	147[a] (28)	209[a] (69)	433 (66)
Chatanika River				
Upper Section	670 (111)	312 (62)	271 (47)	252 (41)
Lower Section	na	242[b] (52)	158[b] (69)	89 (9)
Goodpaster River	145 (15)	157 (17)	138 (16)	217 (27)

[a] 1991 and 1992 Salcha River estimates did not include Arctic grayling less than 200 mm FL.

[b] 1991 and 1992 lower section of the Chatanika extended approximately 24 km farther downstream than the 1993 study section.

greater within the upper section compared to the lower section of the Salcha River study area. Density of sublegal-length Arctic grayling accounted for the greater density of Arctic grayling ≥ 150 mm FL within the lower section compared to the upper section. Density of Arctic grayling ≥ 150 mm FL was greater within the Salcha River study area than either the Chatanika or Goodpaster river study areas (Figure 6).

Estimated abundance of Arctic grayling within the Salcha River study area has increased since 1991. This increase was probably due to good recruitment of fish ≥ 150 mm FL in 1990, 1992 and 1993 (1987, 1988, and 1990 year classes). In addition to good recruitment, this increase may be attributed to good survival of age-3 and -4 Arctic grayling since 1988. It is hypothesized that the good recruitment was a result of favorable environmental conditions and the high survival a result of the 12-inch legal-length limit imposed in 1988. An alternative to the minimum length-limit hypothesis is that favorable environmental conditions during the same period may explain the good survival of sublegal-length fish as well as good recruitment. The Salcha River stock assessment data, however, supports the hypothesis of Clark et al. (1991) that the lower fishing mortality of prespawners will increase spawner abundance[2]. The year-classes most affected by the length limit have remained strong. The 1987 year-class remained strong through 1992 and the 1988 year-class remained strong through 1993. Furthermore, the data indicated that recruitment of fish ≥ 150 mm FL in 1990 increased the abundance of legal-length Arctic grayling in 1993. Lower recruitment of fish ≥ 150 mm FL in 1991, however, may buffer any increase in abundance of legal-length Arctic grayling in 1994 but abundance of legal-length Arctic grayling should increase again in 1995 and 1996 due to good recruitment in 1992 and strong recruitment in 1993.

CHATANIKA RIVER

Abundance and stock composition of Arctic grayling were estimated within a 78.2-km portion of the Chatanika River in 1993. The Chatanika River study area extended from 5 km above the Elliott Highway Bridge downstream to 24 km above the Murphy Dome Road extension (Figure 7). For comparison purposes, prior investigators estimated Arctic grayling abundance and stock composition, at minimum, within the upper 28.8 km of this same study area each year since 1990 (Clark et al. 1991; Fleming et al. 1992; Ridder et al. 1993). In addition, abundance of Arctic grayling was estimated within an index area near the Elliott Highway Bridge in 1972 (Tack 1973), 1982 (Holmes 1983), 1984 (Holmes 1985), and 1985 (Holmes et al. 1986; Appendix B2).

Study Area and Fishery Description

The Chatanika River is a runoff stream that flows southwest out of the White Mountains, draining through Minto Flats into the Tolovana River (Figure 1). The Chatanika River is formed by the confluence of Faith and McManus creeks. This river parallels the Steese Highway for approximately 70 km, continues in a westerly direction across the Elliott Highway, and continues on to the

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2 The amount of reduction in fishing mortality during this period is not known. Mills (1993) reported that 92% of Arctic grayling < 12 in TL caught from the Salcha River were not kept but were released. How much of this percent was due to the 12 in legal-length regulation is not known.

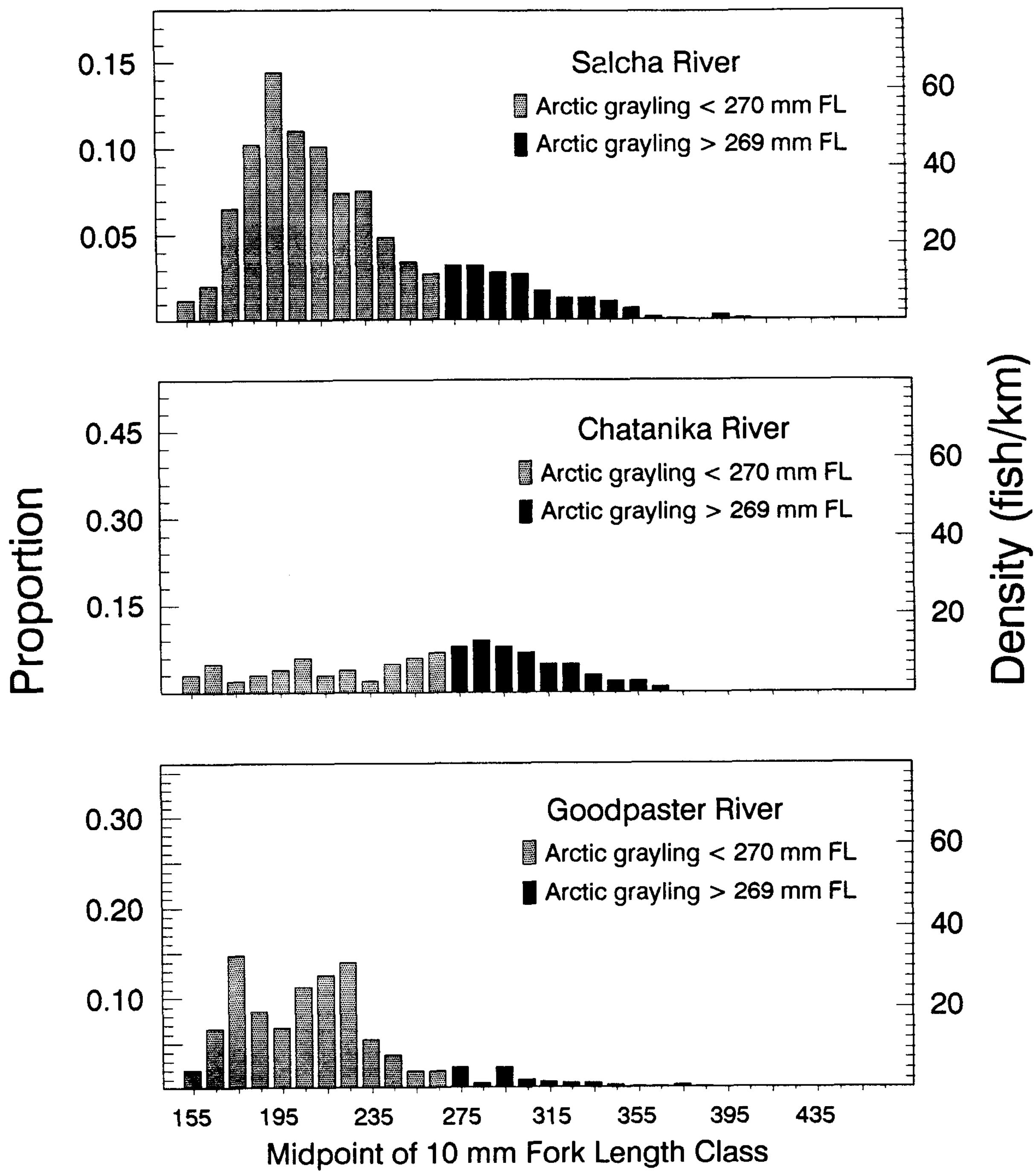

Figure 6. Estimated proportions and densities of Arctic grayling > 149 mm FL by 10 mm length increments within the Salcha, Chatanika, and Goodpaster river study areas during 1993.

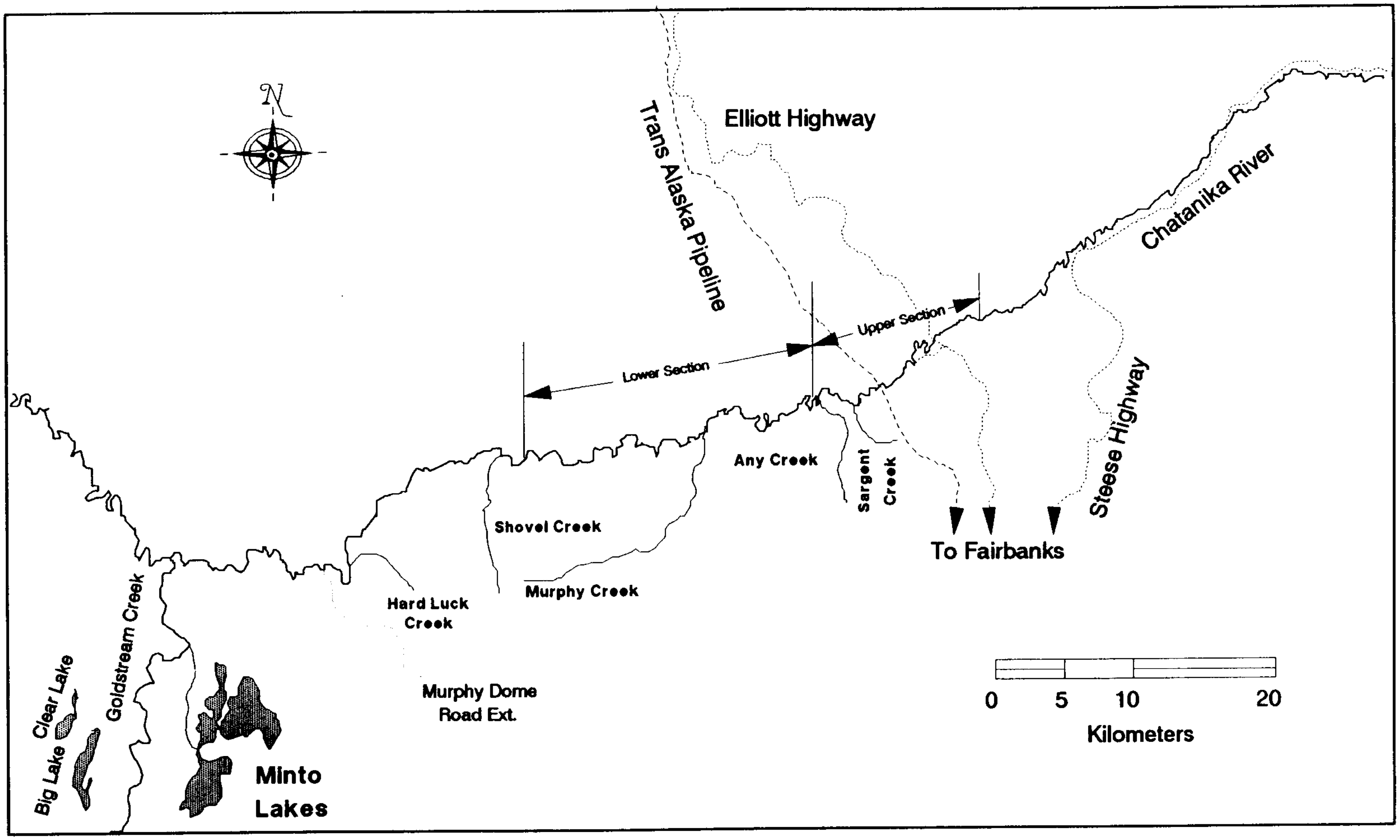

Figure 7. Chatanika River drainage.

Tolovana River. The Chatanika River study section is characterized by moderate gradient, meandering stretches, narrow to wide channels, and exposed gravel bars. There is a history of placer mining within the Chatanika River drainage. As of 1986, there were placer mining operations on portions of Faith, Sourdough, No Name, and Flat creeks of the upper Chatanika River (Townsend 1987). Townsend (1987) also reported mining activity on Goldstream Creek, which drains into the study area.

The Chatanika River fisheries are road accessible along the Steese Highway, from the Elliott Highway Bridge, and at the end of Murphy Dome Road extension. A boat ramp, parking lot, picnic, and camping area are available at the Elliott Highway Bridge, a camping and picnic area at 101-km Steese Highway, and a campground at 98-km Steese Highway. However, access to the study area is limited to float plane or river boat launched from the Elliott Highway Bridge boat ramp or a gravel bar at the end of Murphy Dome extension.

More than 50% of all fish caught (released or kept) in the Chatanika River in 1992 were Arctic grayling. In addition to Arctic grayling, fish caught in the Chatanika River in 1992 included (from greatest to least number caught): whitefish, northern pike, coho salmon *Oncorhynchus kisutch*, sheefish *Stenodus leucichthys*, chinook salmon, chum salmon, and burbot (Mills 1993).

Prior to 1977, information collected from Chatanika River Arctic grayling fishermen was sparse. Creel survey data for harvest rates were obtained during the summers of 1953 through 1958 and 1974. Harvest rates ranged from 0.13 Arctic grayling per hour to 0.78 Arctic grayling per hour from 1953 through 1958 (Warner 1959b); and 1.02 Arctic grayling per hour in 1974 (Kramer 1975).

Each year since 1977, Mills (1979-1993) estimated annual harvest and effort on the Chatanika River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Chatanika River was 5,713 fish, ranging from a high in 1983 of 9,766 and a low in 1992 of 1,751. Average effort on the Chatanika River for all species of sport fish was 9,016 angler-days, ranging from a high in 1989 of 12,210 angler-days to a low in 1981 of 4,691 angler-days. In addition, each year since 1990, Mills (1991-1993) estimated annual fish caught (fish harvested plus fish caught and released) on the Chatanika River (Table 2). The average annual catch of Arctic grayling on the Chatanika River from 1990 through 1992 was 14,120 fish. In addition to the 1987 harvest data provided by Mills (1988), Baker (1988) estimated that the catch rate near the Elliott Highway Bridge was 0.02 Arctic grayling per angler-hour fished from May through June 1987.

The low estimated harvest rates in the early 1950's prompted fishery managers to restrict the harvest of Arctic grayling from the Chatanika River to fish 305 mm (12 in) or greater in total length (Wojcik 1954; 1955) between 1955 and 1958. Similarly, sport fishing regulations were restricted prior to the 1992 fishing season to protect the Chatanika River Arctic grayling fishery from decline. These regulations were designed to:

1) eliminate the harvest of Arctic grayling during the spawning period (1 April to the first Saturday in June);

2) restrict methods of catching Arctic grayling during the spawning period to unbaited, single-hook artificial lures; and,

3) restrict the harvest of Arctic grayling to fish 305 mm (12 in) or greater in total length in the portion of the Chatanika River upstream from a point 1.6 km above the Elliott Highway Bridge (no size restriction within the study area).

Methods

The Chatanika River marking event was completed from 16 through 19 August 1993 and the recapture event from 23 to 26 August 1993. A partial upper caudal finclip was used as a second mark during the marking pass and a partial lower caudal finclip was used to prevent sampling redundancy during the recapture event. In addition to the general methods used for the three rivers, two boats were used during the recapture event to simultaneously sample both banks of the river except in the upper section where one boat was used. Whitefish were also sampled during the Chatanika River experiment but not reported here.

Abundance Estimation:

Abundance of Arctic grayling ≥ 150 mm was estimated within the Chatanika River study area using a modified Petersen estimator (Bailey 1951; 1952), as described by Seber (1982; Appendix D3). To reduce bias from unequal catchability by area, it was necessary to divide the study area into two area strata to estimate abundance; an upper stratum (5 km above the Elliott Highway Bridge downstream to approximately Any Creek) and a lower stratum (from approximately Any Creek downstream to 24 km above the Murphy Dome Road extension).

Length and Age Compositions:

Length and age compositions for Arctic grayling ≥ 150 mm were estimated for each area stratum within the Chatanika River study area. Proportions of fish by length and age were estimated directly for both the upper and lower strata without length stratification (Appendix D4).

Results

Investigators handled 2,172 unique Arctic grayling (≥ 150 mm FL) during the Chatanika River mark-recapture experiment. During the marking event, 1,375 Arctic grayling were tagged and released alive. During the recapture event, 918 Arctic grayling were examined for marks. Of these 918 fish, 797 were unique and 121 were recaptures from the marking event. Of the 121 recaptured fish, three (2.5% of tagged fish recaptured) lost their tags between events but were identified by the presence of a recent upper caudal finclip. During the marking event two Arctic grayling were killed or severely injured (< 1% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event there were no Arctic grayling killed. Investigators identified 281 Arctic grayling (12.9% of unique fish handled) from prior mark-recapture experiments.

Abundance:

Estimated abundance of Arctic grayling within the Chatanika River study area included fish ≥ 150 FL. There was only one recaptured fish, however, between 150 and 201 mm FL (189 mm FL). Therefore an additional estimate of abundance is presented for that portion of the population that were ≥ 189 mm, disregarding marked fish and fish examined for marks < 189 mm FL. However, there is no between-year comparison for this estimate. There were 165 Arctic grayling marked between 150 and 201 mm FL during the marking event and 172 examined for marks during the recapture event. The bias due to the lack of recaptures below 189 mm FL is assumed to be minimal and the lack of recaptures within this range is probably due to the abundance of fish within the range and not because marked fish were not available for recapture.

Recapture rates of Arctic grayling were significantly different among three approximately equal-length sections of the study area (χ = 15.49, 2 d.f., $P < 0.01$). The middle and lower of these, however, were similar (χ = 0.49, 1 d.f., $P = 0.48$). Furthermore, maximal difference in catchability was obtained by dividing the study area into two strata at approximately 26 km downstream of the Elliott Highway Bridge (χ = 13.92, 1 d.f., $P < 0.01$). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) for the upper stratum was 0.08 and for the lower stratum 0.17 (Figure 8).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured did not indicate movement between sections (Table 7). Of recaptured Arctic grayling with known capture histories by location, nine of 109 (7.6%) moved from one section to another between events (marking location of three fish were not known). This was viewed as non significant movement between sections because it was less than 10%. No movement between sections and a difference in catchability between sections of the study area indicated that none of the "or" conditions of assumption 2 were satisfied. Bias from different catchabilities between sections was compensated for by following the methodology outlined in Appendix D1 (Case III). The Bailey estimator was chosen to estimate abundance of each area stratum.

There was no significant difference between the length distributions of fish marked and fish recaptured within the upper stratum ($D = 0.20$, $P = 0.17$; Figure 9-A1) or the lower stratum ($D = 0.13$, $P = 0.13$; Figure 9-A2). This result indicated that one of the "or" conditions of assumption 2 was satisfied in both strata. Specifically, at minimum there was no length selectivity during the recapture event. Therefore, an unstratified abundance estimate was used to estimate Arctic grayling abundance within both strata (Appendix D2).

Estimated abundance of Arctic grayling ≥ 150 mm FL within the Chatanika River study area was 11,766 fish (SE = 1,273; CV = 11%; Table 8) and of Arctic grayling ≥ 189 mm FL was 9,506 fish (SE = 971; CV = 10%). Estimated densities of Arctic grayling ≥ 150 mm FL varied between sections of the Chatanika study area; 252 (SE = 41) fish per kilometer in the upper section and 89 (SE = 9) fish per kilometer in the lower section ($Z = 11.6$, $P < 0.01$).

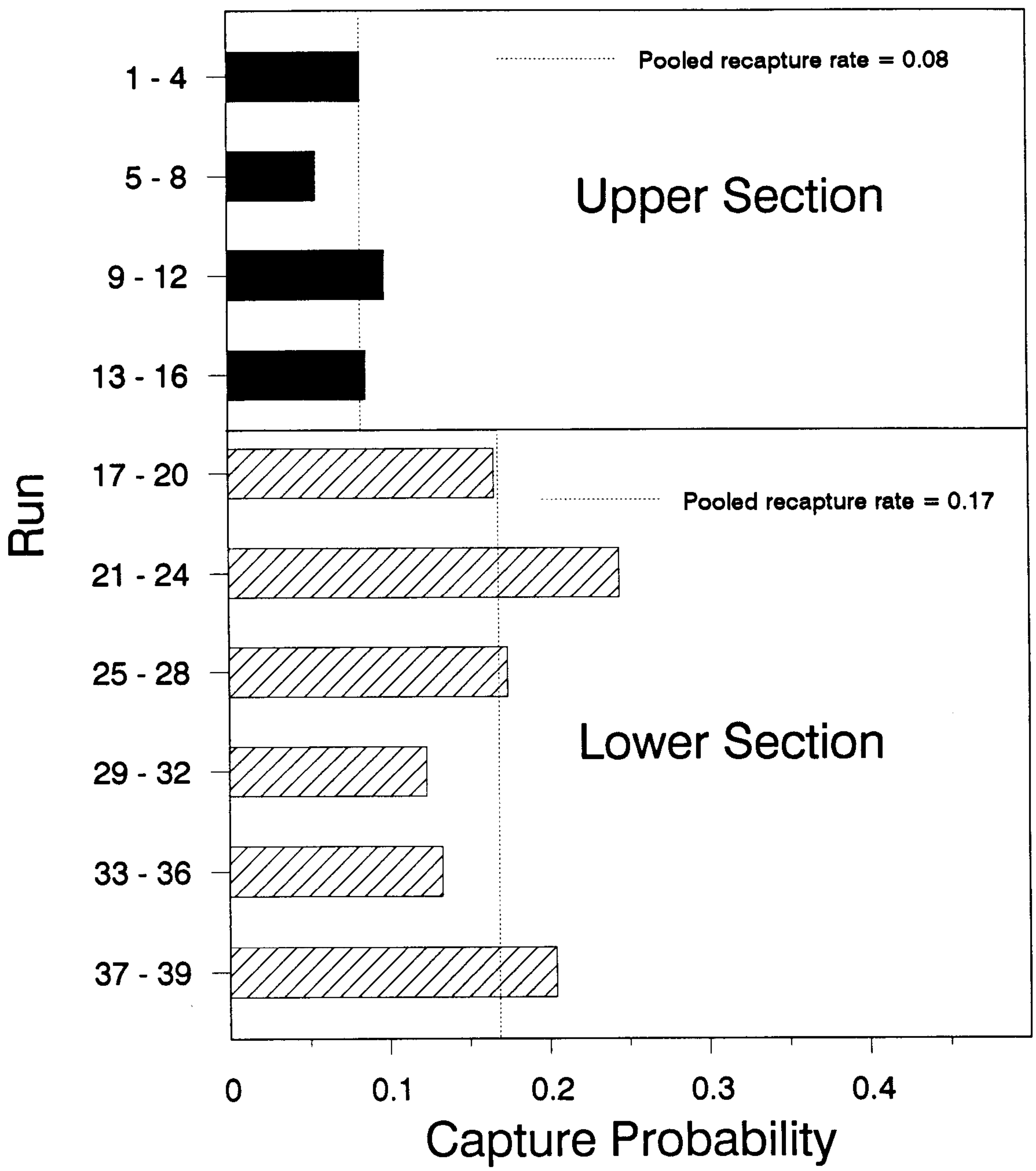

Figure 8. Estimated capture probabilities (number of fish marked in the first event and recaptured in the second event divided by the total number of fish captured in the second event) for Arctic grayling in two study sections of the middle Chatanika River (approximately 5 km above the Elliott Highway bridge down to 24 km above Murphy Dome Road).

Table 7. Number of Arctic grayling recaptured[a] in a section and run[b] of the Chatanika River summarized by the section and run in which the fish was originally marked. Fish along the diagonal did not move out of the run in which it was originally marked.

Number Recaptured — Upstream (Section III)

Mark Section	Mark Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
III	1	0	2	1			1										
	2		0	1													
	3			1													
	4			1	1												
	5					0											
	6						1										
	7							3									
	8								0	1							
	9									1							
	10										1						
	11											3					
	12												3				
	13													1			
	14														1		
	15															1	
	16											1				2	1
II	17											1	1		1	1	
	18–26																
I	27–39																
Total		0	2	4	1	0	2	3	0	2	1	5	4	1	2	4	1

Number Recaptured — Midstream (Section II)

Mark Section	Mark Run	17	18	19	20	21	22	23	24	25	26
III	1–13										
	14										1
	15										
	16	1									
II	17	8									
	18	1	9								
	19	2	1	4							
	20			1	0	1					
	21					2					
	22	1		1			2	1			
	23							0			
	24						1		0	1	
	25									1	
	26					2					0
I	27					1					
	28–39										
Total		13	11	7	0	6	3	1	0	2	1

Number Recaptured — Downstream (Section I)

Mark Section	Mark Run	27	28	29	30	31	32	33	34	35	36	37	38	39
III	1–16													
II	17													
	18				1									
	19													
	20		1											
	21–26													
I	27	0												
	28		0											
	29			0										
	30				1									
	31					0								
	32						6	1						
	33							2	1					
	34								0					
	35									4	1			
	36										2			2
	37										1	1	2	
	38					1							10	1
	39													4
Total		0	1	0	2	1	6	3	1	4	4	1	12	7

- continued -

Table 7. (Page 2 of 2).

Mark		Number Moved (Not Moved)	
Section	Run	Between Sections	Between Runs
	1	0 (4)	4 (0)
	2	0 (1)	1 (0)
	3	0 (1)	0 (1)
	4	0 (2)	1 (1)
	5	0 (0)	0 (0)
	6	0 (1)	0 (1)
	7	0 (3)	0 (3)
III	8	0 (1)	1 (0)
	9	0 (1)	0 (1)
	10	0 (1)	0 (1)
	11	0 (3)	0 (3)
	12	0 (3)	0 (3)
	13	0 (1)	0 (1)
	14	1 (1)	1 (1)
	15	0 (1)	0 (1)
	16	1 (4)	4 (1)
	17	4 (10)	6 (8)
	18	1 (10)	2 (9)
	19	0 (7)	3 (4)
	20	1 (2)	3 (0)
II	21	0 (2)	0 (2)
	22	0 (5)	3 (2)
	23	0 (0)	0 (0)
	24	0 (2)	2 (0)
	25	0 (1)	0 (1)
	26	0 (2)	2 (0)
	27	1 (0)	1 (0)
	28	0 (0)	0 (0)
	29	0 (0)	0 (0)
	30	0 (1)	0 (1)
	31	0 (0)	0 (0)
I	32	0 (7)	1 (6)
	33	0 (3)	1 (2)
	34	0 (0)	0 (0)
	35	0 (5)	1 (4)
	36	0 (4)	2 (2)
	37	0 (4)	3 (1)
	38	0 (12)	2 (10)
	39	0 (4)	0 (4)
Total		9 (109)	44 (74)

[a] This table does not include three marked fish that were recaptured without a tag. Movement could not be determined because the run they were marked in is not known.

[b] Recapture locations are broken into river sections (see Methods) and run number. A run is approximately 1.8 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at the head of the uppermost river section.

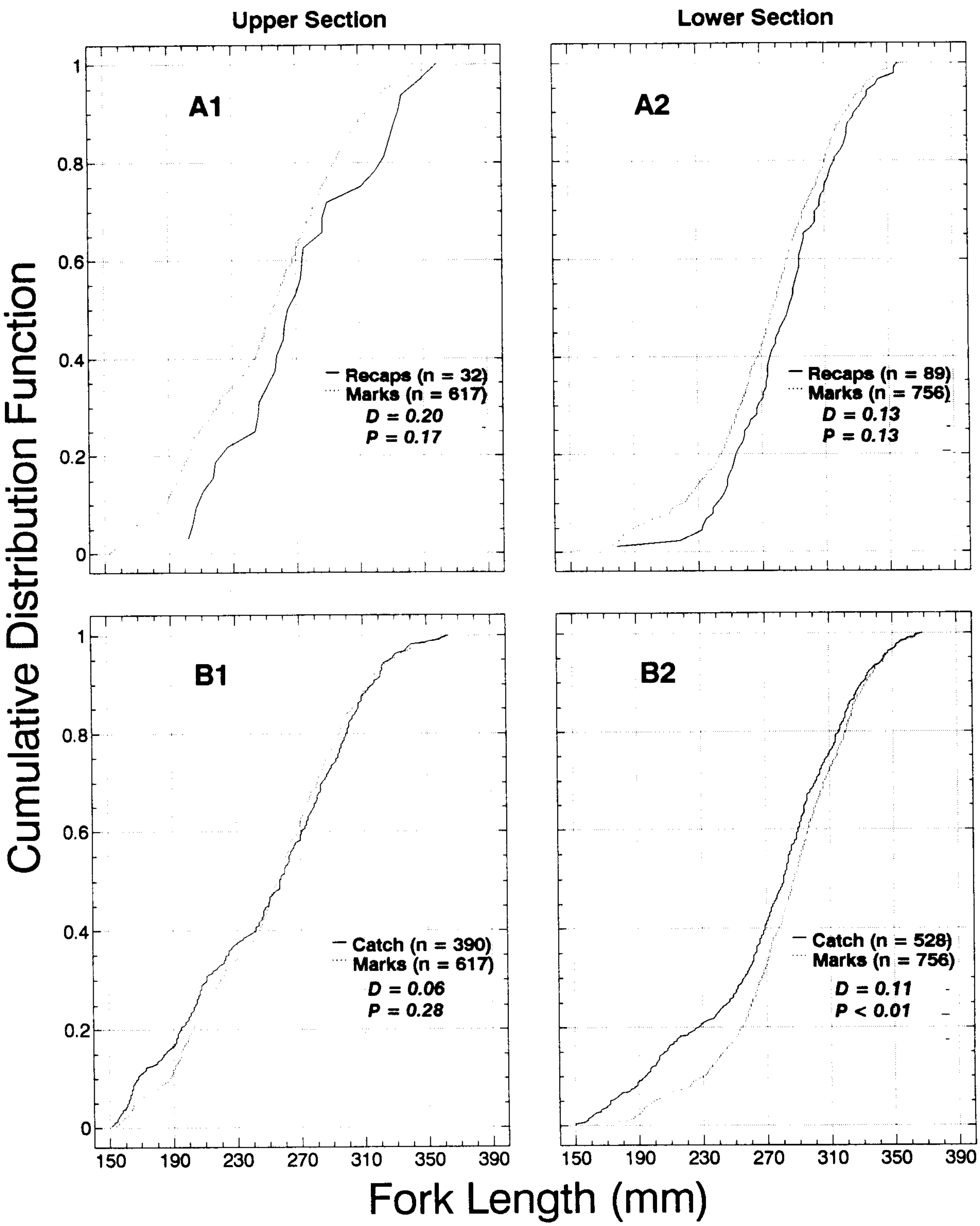

Figure 9. Cumulative distribution functions of fork lengths of Arctic grayling captured in two sections of the Chatanika River. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

Table 8. Estimated abundance (N), number of fish marked (M), number of fish examined for marks (C), number of fish recaptured with marks (R), and capture probabilities (R/C) of Arctic grayling (FL ≥ 150 mm) within the Chatanika River study area, 16 through 26 August 1993, summarized by two study sections with different capture probabilities ($\chi^2 = 13.92$, 1 d.f., $P < 0.01$).

Section[a]	Mark M	Catch C	Recap R	R/C	N[b]	SE[N]
Upper[c]	617	390	32	0.08	7,311	1,200
Lower[d]	758	528	89	0.17	4,455	425
Total	1,375	918	121	0.13	11,766	1,273

[a] Sections were determined by dividing the study area at the point that maximized the difference between capture probabilities (R/C).

[b] The Bailey (1951; 1952) estimator was used to estimate abundance of each section; section estimates were summed to estimate the total abundance of Arctic grayling within the study area.

[c] Boundaries for the upper section were approximately, five kilometers above the Elliott Highway bridge downstream to Any Creek.

[d] Boundaries for the lower section were approximately, Any Creek downstream to approximately three kilometers above Shovel Creek (about 24 km above the Murphy Dome Road extension).

Length and Age Compositions:

For the upper stratum of the Chatanika River study area, there was not a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.20$, $P = 0.17$; Figure 9-A1), or between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.06$, $P = 0.28$; Figure 9-B1). This indicated that there was no difference in catchability by length during either the marking or recapture events within the upper stratum.

For the lower stratum of the Chatanika River study area, there was not a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.13$, $P = 0.13$; Figure 9-A2). There was a significant difference, however, between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.11$, $P < 0.01$; Figure 9-B2). This indicated that there was no difference in catchability by length during the recapture event but there was a difference during the marking event within the upper stratum. Therefore, lengths from the recapture event were used to directly estimate length composition for both sections of the river without stratification.

Fork lengths of Arctic grayling captured during the recapture event were used to estimate length composition of Arctic grayling ≥ 150 mm FL within both strata of the Chatanika River study area. Fork lengths measured from 918 Arctic grayling (390 from the upper stratum and 528 from the lower stratum) ≥ 150 mm from the Chatanika River recapture event ranged from 150 to 369 mm (mean = 263 mm, SE = 2 mm). There was greater density of Arctic grayling ≥ 270 mm FL within the upper stratum than within the lower stratum ($Z = 5.36$; $P < 0.01$). Also, there was greater density of Arctic grayling < 270 mm FL within the upper stratum than within the lower stratum ($Z = 11.32$, $P < 0.01$). The estimated proportion of Arctic grayling ≥ 270 mm FL within the Chatanika River study area was 0.49 (SE = 0.04; Figure 10). The largest Arctic grayling sampled from the Chatanika River in 1993 was 386 mm FL, which was captured during the marking event.

Ages from Arctic grayling captured during the recapture event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within both strata of the Chatanika River study area. Ages were estimated from 639 of 918 Arctic grayling captured during the recapture event. Age classes, estimated from the scales of Arctic grayling ≥ 150 mm FL from the Chatanika River captured during the recapture event, ranged from age-1 to age-13. The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Chatanika River study area were age-6 (0.25, SE = 0.02) and age-3 (0.21, SE = 0.02; Table 9). A larger proportion of age-3 Arctic grayling was estimated within the upper stratum of the study area compared to the lower stratum ($Z = 2.73$, $P < 0.01$). A greater density of all age classes within the upper stratum accounted for the absolute difference in Arctic grayling density between strata (Table 9).

Discussion

Harvest of Arctic grayling from the Chatanika River has decreased every year since 1988 (80% from 1988 to 1992) and fishing effort has decreased every year since 1989 (44% from 1989 to 1992; Table 1). Explanations for the reduced harvest and fishing effort are confounded because, unlike the Salcha and

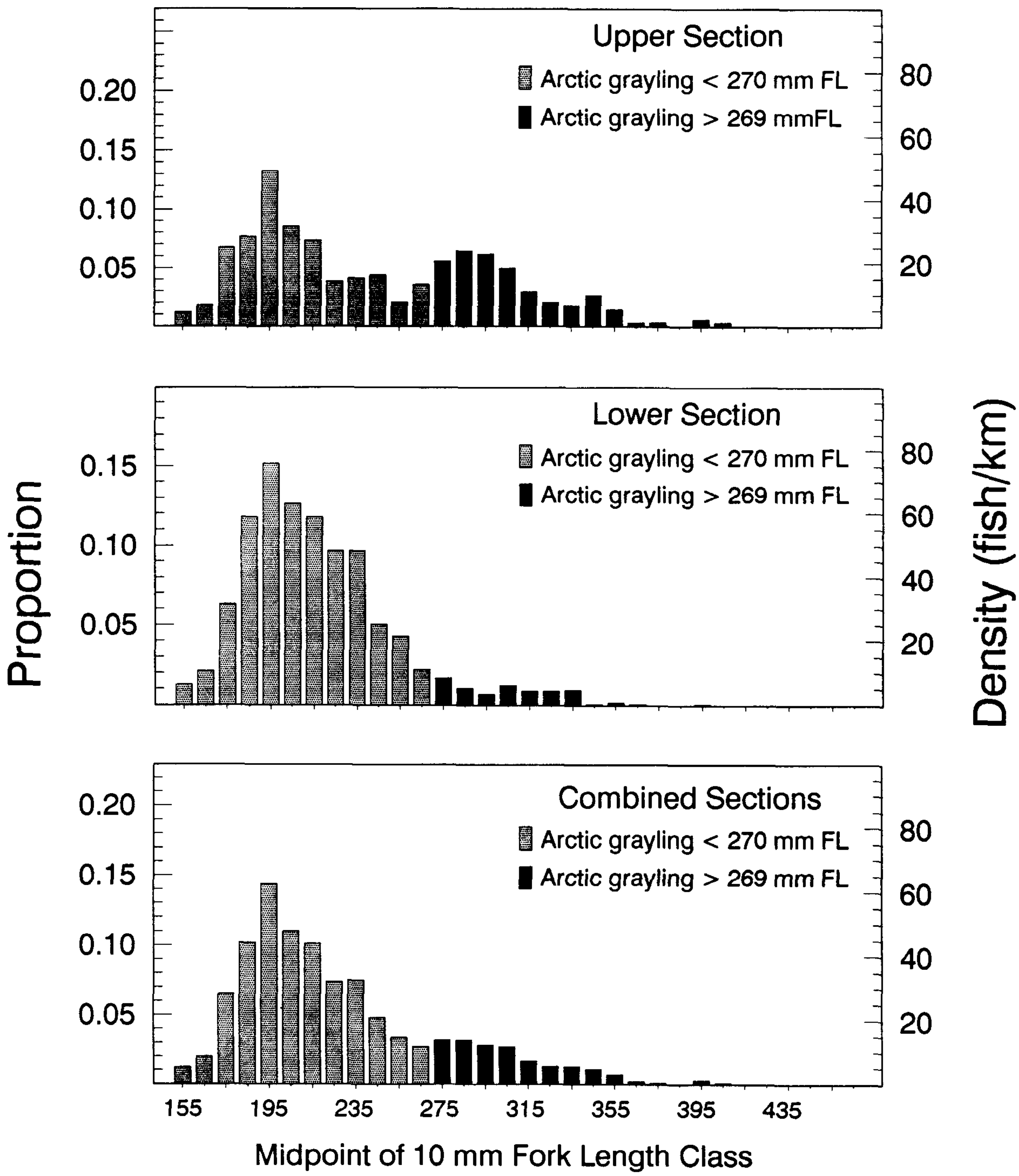

Figure 10. Estimated proportions and densities of Arctic grayling > 149 mm FL by 10 mm length increments within the upper, lower, and combined sections of the Chatanika River study area during August 1993.

Table 9. Estimated abundance (N), standard error of abundance (SE[N]), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age and river section within the Chatanika River study area (age samples from fish captured during the recapture event, 23 - 26 August, 1993).

	River Section											
	Upper[a]				Lower[b]				Combined			
Age Class	N	SE[N]	p	SE[p]	N	SE[N]	p	SE[p]	N	SE[N]	p	SE[p]
1	24	17	0.00	0.00	-	-	0.00	0.00	24	18	0.00	0.00
2	1,287	260	0.18	0.02	461	98	0.10	0.02	1,748	224	0.15	0.01
3	1,749	322	0.24	0.02	672	109	0.15	0.02	2,421	355	0.21	0.02
4	267	87	0.04	0.01	198	47	0.04	0.01	465	128	0.04	0.01
5	1,263	250	0.17	0.02	633	107	0.14	0.02	1,896	310	0.16	0.02
6	1,676	311	0.23	0.02	1,226	148	0.28	0.02	2,902	395	0.25	0.02
7	461	102	0.06	0.01	501	100	0.11	0.02	962	155	0.08	0.01
8	170	76	0.02	0.01	264	51	0.06	0.01	434	127	0.04	0.01
9	170	76	0.02	0.01	171	47	0.04	0.01	341	123	0.03	0.01
10	146	50	0.02	0.01	145	46	0.03	0.01	291	120	0.02	0.01
11	49	25	0.01	0.00	105	45	0.02	0.01	154	117	0.01	0.01
12	24	17	0.00	0.00	79	32	0.02	0.01	103	94	0.01	0.01
13	24	17	0.00	0.00	-	-	0.00	0.00	24	18	0.00	0.00
Totals	7,311	1,200	1.00	-	4,455	425	1.00	-	11,765	1,273	1.00	-

[a] Boundaries for the upper section were approximately, five km above the Elliott Highway Bridge downstream to Any Creek.

[b] Boundaries for the lower section were approximately, Any Creek downstream to approximately three km above Shovel Creek (about 24 km above the Murphy Dome Road extension).

Goodpaster River study areas, the Chatanika River study area covers only a portion of the Chatanika River that is actively fished and regulations are different inside and outside of the study area. Roadside access to the Chatanika River is available along a 70-km section of the river outside of the study site. The proportion of the river-wide harvest and effort that takes place within the study area is not known. The decline in harvest and fishing effort, however, is probably a result of regulations, increased catch-and-release fishing, and decreased density of Arctic grayling within the study area during this same period.

It is difficult to make comparisons of density from one year to the next because the study area has changed each year. However, within a study section of the Chatanika River that was similar to each investigation since 1991 (a few kilometers above the Elliott Highway Bridge downstream to approximately Any Creek [3]) density of Arctic grayling ≥ 150 mm FL has decreased (Table 6). Although not directly comparable, it should also be noted that the density of Arctic grayling ≥ 150 mm FL below Any Creek has also decreased since 1991 (Table 6).

The strong recruitment of the 1987 Arctic grayling year class reported by Ridder et al. (1993) remains evident within the composition of Arctic grayling in the Chatanika River study area, but is not followed by another year class of similar strength (Table 9). Even though there was a high proportion of Arctic grayling ≥ 270 mm FL within the Chatanika River study area, the data suggest that this will not continue but will decline because of the low proportion of Arctic grayling < 270 mm FL (Figure 10). Within the upper section of the study area, the proportion of Arctic grayling from 150 mm to 269 mm FL remained constant at 0.84 ($SE = 0.03$) in 1991 and 1992 but decreased to 0.58 ($SE = 0.02$) in 1993 ($Z = 2.69$, $P < 0.01$) . This decrease in proportion of smaller fish, combined with the decrease in abundance indicates that there will be a decline in Arctic grayling abundance over the next few years within the study area.

GOODPASTER RIVER

Abundance and stock composition of Arctic grayling were estimated within a 50-km portion of the Goodpaster River in 1993. The Goodpaster River study area extended from river kilometer 52.3 downstream to river kilometer 2.7 (Figure 11). For comparison purposes, prior investigators estimated Arctic grayling abundance and stock compositions within this same study area in 1973 (Tack 1974) and 1974 (Tack 1975); and in each year since 1988 (Ridder 1989; Clark and Ridder 1990; Clark et al. 1991; Fleming et al. 1992; Ridder et al. 1993). In addition, abundance of Arctic grayling was estimated within two 5-km index sections 11 different years from 1975 through 1987 (Appendix C1).

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[3] This section of the study area has been referred to as the upper section (present report and Ridder et al. 1993), the Middle Chatanika River (Fleming et al. 1992), and the Chatanika River (Clark et al. 1991).

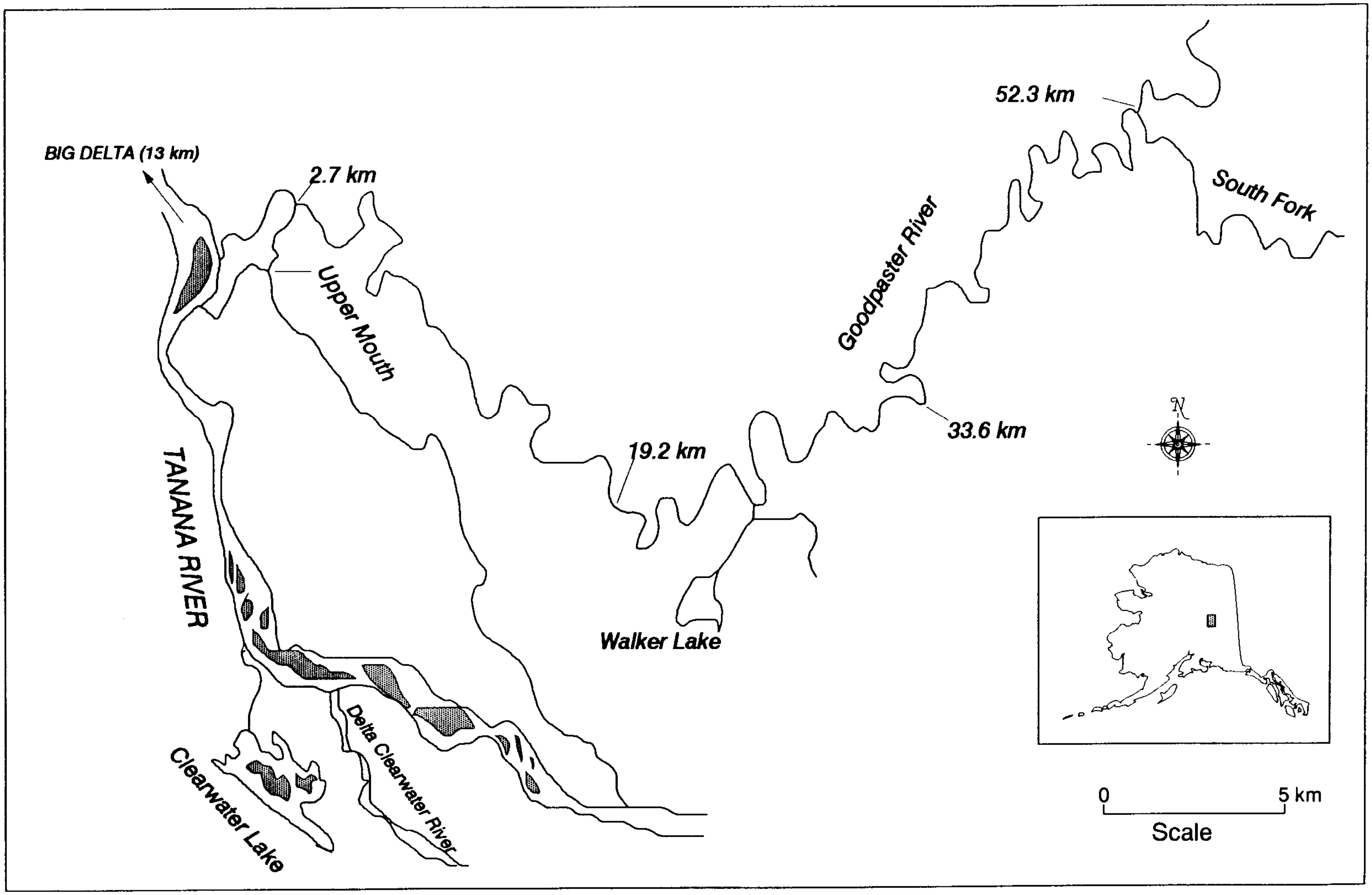

Figure 11. Goodpaster River drainage.

Study Area and Fishery Description

The Goodpaster River is a rapid runoff stream that originates in the Tanana Hills and flows southwest for 224 km to its confluence with the Tanana River, which is 16 km north of Delta Junction (Figure 1). The Goodpaster River drainage includes an area of approximately 4,100 km^2 (Figure 11). The river has 13 named tributaries, the largest of which are the Eisenmenger Fork (38 km in length) at river kilometer 184 and the South Fork (64 km in length) at river kilometer 52.3. Ridder et al. (1993) characterized the current study area as generally shallow (< 1 m deep), wide (~60 m across), slow moving, meandering, slightly tannic stained, and susceptible to rapid fluctuations in water level. In addition, Van Wyhe (1964) described the current study area of the Goodpaster River as low in productivity due to sparse aquatic vegetation and predominant sandy bottom. In contrast, he described the river above the study area as high in productivity due to a coarse gravel bottom, high density of aquatic vegetation, and high density of Arctic grayling prey organisms.

Previous investigators hypothesized that the Goodpaster River serves as a spawning and nursery stream for a portion of the summer Arctic grayling populations of the Richardson and Delta Clearwater rivers (Reed 1961; Nagata 1963; Roguski 1967). Reed (1961) observed that the majority of Arctic grayling tagged within the Goodpaster River were age-2 and -3 and recoveries of Goodpaster fish within clearwater streams were age-5 and older. He suggested an age-size relationship for interstream movements. In addition, scale pattern analysis of age-3 Arctic grayling indicated that the Goodpaster River may be the source of up to 51% of the Delta Clearwater River Arctic grayling population (Ridder 1983).

Ridder (1991) supported these movement hypotheses with additional data reported in a summary of Arctic grayling recaptures within the middle Tanana River drainage. He reported that Goodpaster River Arctic grayling tags were recovered from six streams other than the Goodpaster River. Furthermore, recovery rates of Goodpaster River tags in these other streams were related to the time of year that the fish were tagged. Of 64 Goodpaster River tags that were put out in June and later recovered, 58% were recovered in other streams and predominantly from the Delta Clearwater River. However, of 98 Goodpaster River tags that were put out in August and later recovered, only 16% were recovered in other streams. This suggests that some Arctic grayling enter the Goodpaster River in the spring to spawn and then leave, while others remain in the river for the summer. Of fish that remain within the Goodpaster River, Tack (1974; 1980) described an upstream movement, both before and after spawning but little movement during the summer. In addition, he reported smaller and younger fish within the present study area compared to further upstream.

The Goodpaster River fisheries are only accessible by riverboat or airplane. However, riverboat travel on the Goodpaster River is limited to the lower 98 km of the main-stem river and the lower 5 km of the South Fork. Float plane access is limited to the lower 36 km of the river. Boat launches are located at Big Delta on the Tanana River (22.4 km downstream) and at Clearwater Lake (11.2 km upstream). Landing strips are located at Central Creek at river kilometer 118 and at Tibbs Creek, a tributary of the Eisenmenger Fork. There are approximately 50 cabins on the river and all but five are located between river kilometers 11 and 48.

More than 90% of all fish caught (released or kept) in the Goodpaster River in 1992 were Arctic grayling. In addition to Arctic grayling, fish caught in the Goodpaster River in 1992 included (from the greatest to least number caught): northern pike, chum salmon, and burbot (Mills 1993). There is a small run of chinook and chum salmon in the Goodpaster River but salmon harvest is prohibited by regulation.

Prior to 1983, information collected from Goodpaster River fishermen was sparse. Tack (1974) conducted an on site creel survey in 1973. Harvest rates in 1973 ranged from 0.69 to 1.63 Arctic grayling per hour. Estimated harvest of Arctic grayling during that year was 2,236 fish and estimated mean length of the harvest was 241 mm FL (n = 241). The harvest was predominantly from the lower 53 km of the river and effort was mainly from residents of the Delta Junction area.

Each year since 1983, Mills (1984-1993) estimated annual harvest and effort on the Goodpaster River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Goodpaster River was 1,558 fish, ranging from a high in 1983 of 3,021 and a low in 1991 of 636. Average effort on the Goodpaster River for all species of sport fish was 1,686 angler-days, ranging from a high in 1987 of 3,061 angler-days to a low in 1984 of 766 angler-days. In addition, each year since 1990, Mills (1991-1993) estimated annual fish caught (fish harvested plus fish caught and released) on the Goodpaster River (Table 2). The average annual catch of Arctic grayling on the Goodpaster River from 1990 through 1992 was 2,615 fish.

Methods

The Goodpaster River marking event was completed from 3 through 5 August 1993 and the recapture event from 10 through 13 August 1993. A partial upper caudal finclip was used as a second mark during the marking pass and a partial lower caudal finclip was used to prevent sampling redundancy during the recapture event. An exception to the general methods used for the three rivers was that both banks of the Goodpaster River were not sampled completely during the recapture event. The electrofishing boat alternated river banks, favoring the more productive outside bends over the inside bends, which are typically shallow with sandy bottoms and no overhead cover. Both banks, however, were sampled in areas where both sides of the river offered favorable habitat.

Abundance of Arctic grayling ≥ 150 mm was estimated, directly without stratification, within the Goodpaster River study area using a modified Petersen estimator (Bailey 1951; 1952), as described by Seber (1982; Appendix D3). Length and age compositions for Arctic grayling ≥ 150 mm were also estimated directly without length stratification (Appendix D4).

Results

Investigators handled 1,561 unique Arctic grayling (≥ 150 mm FL) during the Goodpaster River mark-recapture experiment. During the marking event, 730 Arctic grayling were tagged and released alive. During the recapture event, 890 Arctic grayling were examined for marks. Of these 890 fish, 831 were unique and 59 were recaptures from the marking event. Of the 59 recaptured fish, none lost their tags between events. During the marking event one Arctic grayling was killed or severely injured (< 1% of fish handled during the marking event). This fish was not included in the experiment. During the recapture event there were no Arctic grayling killed. Investigators identified 92 Arctic grayling (13.0% of unique fish handled) from prior mark-recapture experiments.

Abundance:

Estimated abundance of Arctic grayling within the Goodpaster River study area included fish ≥ 150 FL.

Recapture rates of Arctic grayling were not significantly different among three approximately equal-length sections of the study area (χ = 0.99, 2 d.f., P = 0.61). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) was 0.06 (Figure 12).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured did not indicate movement between sections (Table 10). Of recaptured Arctic grayling with known capture histories by location, five of 59 (8.5%) moved from one section to another between events. This was viewed as non significant movement between sections because it was less than 10%. No movement between sections, no difference in catchability between sections, and equal effort throughout the study area indicated that one of the "or" conditions of assumption 2 was satisfied. Specifically, at minimum there was no difference in catchability by river section. Therefore, a modified Petersen estimator (Bailey 1951; 1952) was chosen to estimate abundance of Arctic grayling within the study area (Appendix D1; Case I).

There was no significant difference between the length distributions of fish marked and fish recaptured within the study area (D = 0.10, P = 0.63; Figure 13-A). This result indicated that one of the "or" conditions of assumption 2 was satisfied. Specifically, at minimum there was no length selectivity during the recapture event. Therefore, an unstratified abundance estimate was used to estimate Arctic grayling abundance within the Goodpaster River study area (Appendix D2).

Estimated abundance of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area was 10,841 fish (SE = 1,340; CV = 12%). Estimated densities of Arctic grayling ≥ 150 mm FL within the study area was 217 (SE = 27) fish per kilometer.

Length and Age Compositions:

There was no significant difference between the length distributions of fish marked and fish recaptured (D = 0.10, P = 0.63; Figure 13-A). There was a significant difference, however, between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event (D = 0.08, P = 0.02; Figure 13-B). This indicated that there was no difference in catchability by length during the recapture event but there was a difference during the marking event. Therefore, lengths from the recapture event were used to directly estimate length composition for both sections of the river without stratification.

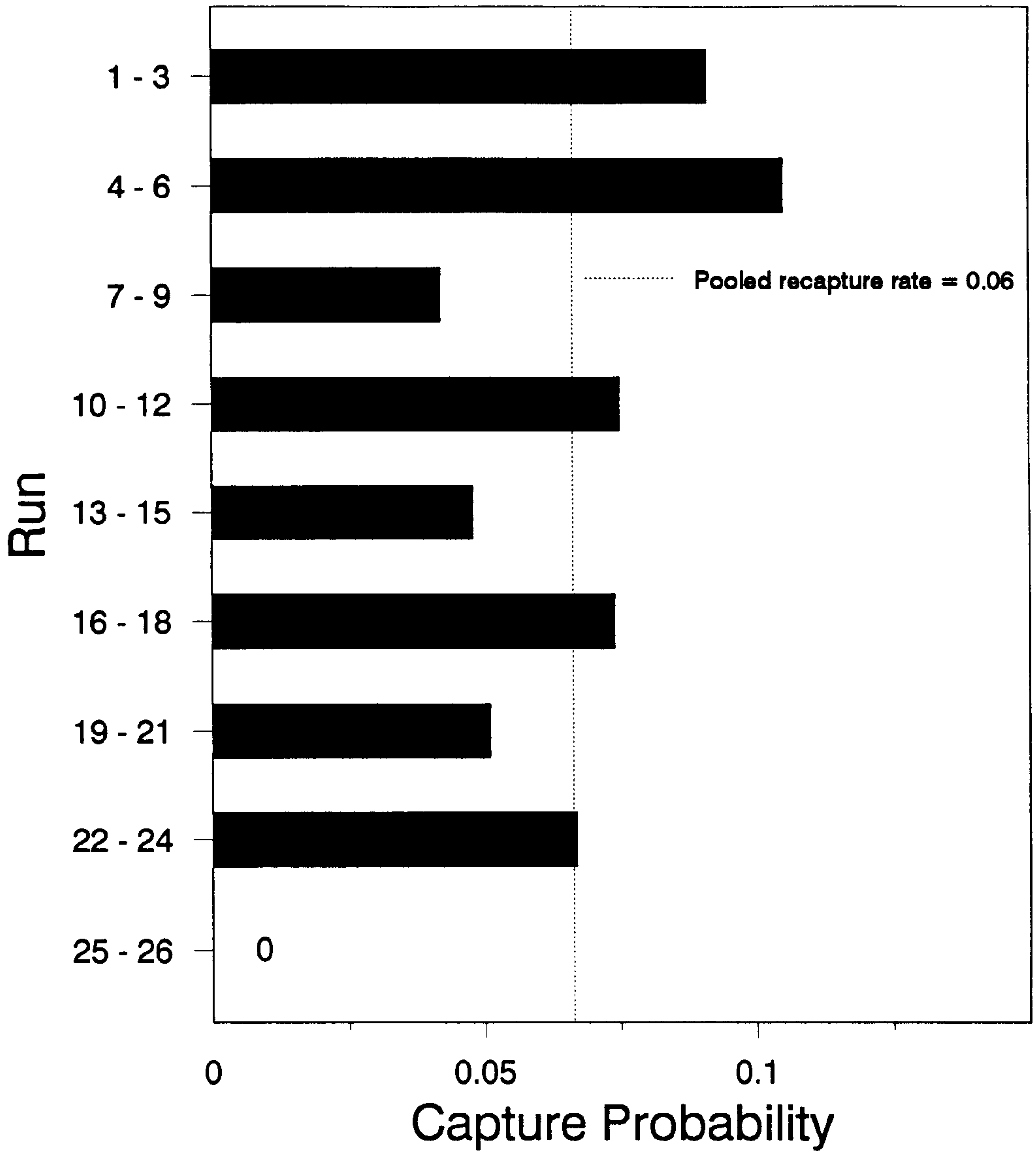

Figure 12. Estimated capture probabilities (number of fish marked in the first event and recaptured in the second event divided by the total number of fish captured in the second event) for Arctic grayling within the lower 50 km of the Goodpaster River.

Table 10. Number of Arctic grayling recaptured in a section and run[a] of the Goodpaster River summarized by the section and run in which the fish was originally marked. Fish along the diagonal did not move out of the run in which it was originally marked.

Mark		Number Recaptured																										Number Moved (or Not Moved)	
		Section III									Section II									Section I									
Section	Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Between Sections	Between Runs
III	1	2	1		1																							0 (4)	2 (2)
	2		2	1																								0 (3)	1 (2)
	3			0																								0 (0)	0 (0)
	4		1		2																							0 (3)	1 (2)
	5					0																						0 (0)	0 (0)
	6			1			1				1																	1 (2)	2 (1)
	7							1																				0 (1)	0 (1)
	8								0																			0 (0)	0 (0)
	9									1																		0 (1)	0 (1)
II	10										1																	0 (1)	0 (1)
	11											4		1														0 (5)	1 (4)
	12												1															0 (1)	0 (1)
	13													0														0 (0)	0 (0)
	14														0													0 (0)	0 (0)
	15															4			1									0 (5)	1 (4)
	16															1	9			1		1						2 (10)	3 (9)
	17																	2	1	1								1 (3)	2 (2)
	18																		4	1								1 (4)	1 (4)
I	19																			2								0 (2)	0 (2)
	20																				0							0 (0)	0 (0)
	21																					1	1					0 (2)	1 (1)
	22																						2					0 (2)	0 (2)
	23																							1				0 (1)	0 (1)
	24																								4			0 (4)	0 (4)
	25																									0		0 (0)	0 (0)
	26																										0	0 (0)	0 (0)
	Total	2	4	2	3	0	1	1	0	1	2	4	1	1	0	5	9	2	6	5	0	2	3	1	4	0	0	5 (54)	15 (44)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 1.8 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 52.3 and run 26 ends at river km 2.7.

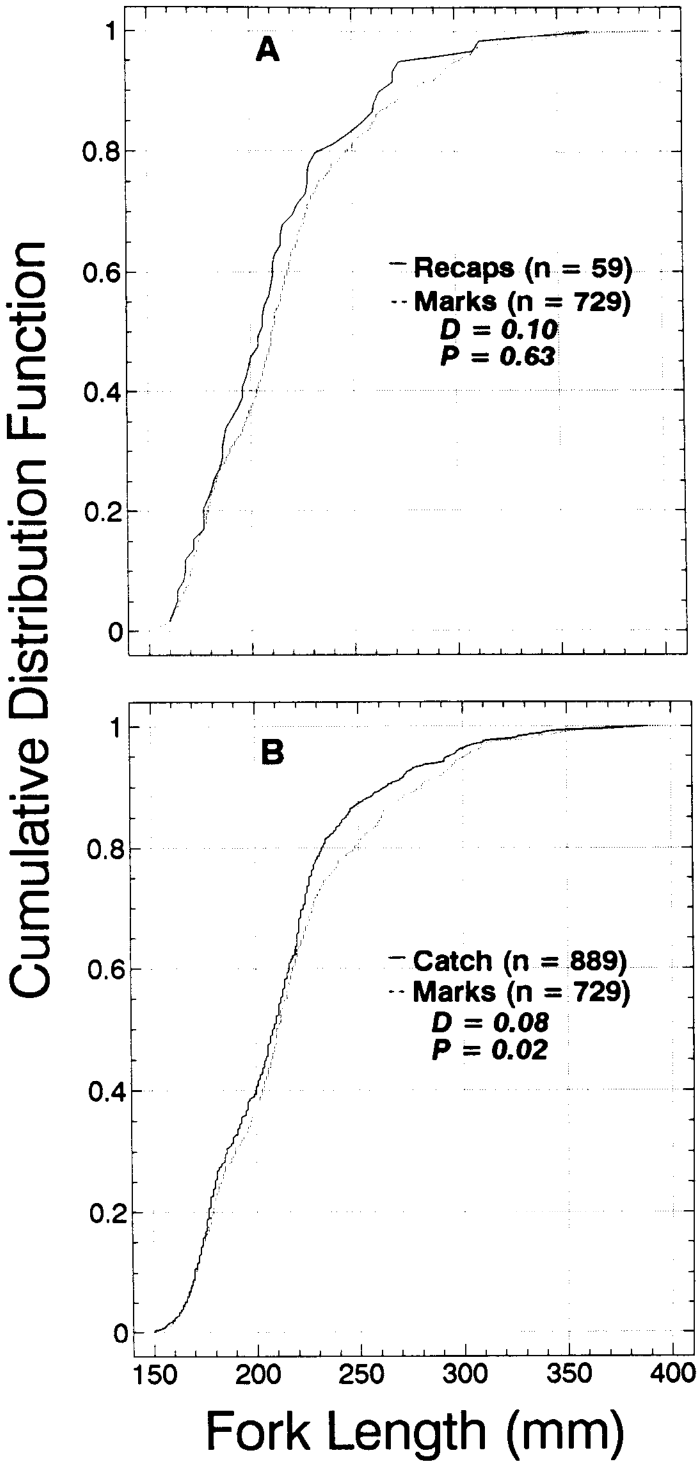

Figure 13. Cumulative distribution functions of fork lengths of Arctic grayling captured in the Goodpaster River. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

Fork lengths from Arctic grayling captured during the recapture event were used to estimate length composition of Arctic grayling ≥ 150 mm FL within the study area. Fork lengths measured from 889 Arctic grayling ≥ 150 mm FL from the Goodpaster River recapture event ranged from 150 to 389 mm FL (mean = 212 mm, SE = 1 mm). The estimated proportion of Arctic grayling from 150 to 269 mm FL within the Goodpaster River study area was 0.91 (SE = 0.01), and ≥ 270 mm FL was 0.09 (SE = 0.01; Figure 14). The largest Arctic grayling sampled from the Goodpaster River in 1993 was 395 mm FL, which was captured in the marking event.

Ages from Arctic grayling captured during the marking event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area. Ages were estimated for 644 of 730 Arctic grayling. Age classes, estimated from the scales of Arctic grayling ≥ 150 mm FL from the Goodpaster River marking event, ranged from age-2 to age-10 (mean = 3.14, SE = 0.05). The age class with the largest proportion of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area was age-3 (0.45, SE = 0.02; Table 11).

Discussion

Harvest of Arctic grayling from the Goodpaster River has decreased 61% since 1989, however, fishing effort on the Goodpaster River during the same period has fluctuated from a high in 1990 to a low in 1991 and back up in 1992 (Table 1). Harvest and fishing effort was lower in 1991 than in any year since 1985 (Table 1). Some fishing effort during this period may have been diverted to catch-and-release but there are no data to support this hypothesis because there are no comparisons for catch-and-release information before 1990 (Table 2). It is believed, however, that catch-and-release fishing has generally increased over the last few years.

It was suggested by Ridder et al. (1993) that Arctic grayling abundance within the Goodpaster River may have been depressed but stable during the years from 1988 through 1992 when compared to historic data, in particular when compared to the estimated abundance of 1973 (Tack 1974). This assessment was probably correct even though the authors characterized the estimates prior to 1988 as low in precision and high in variability. Estimated abundance of Arctic grayling ≥ 150 mm FL within the Salcha River study area, however, increased to 10,841 fish in 1993 from the five-year average of 7,600. This increase was probably due to good recruitment of fish ≥ 150 mm FL in 1992 and 1993 (1989 and 1990 year classes). Nonetheless, Arctic grayling ≥ 150 mm FL within the Goodpaster River study area remained below historic estimates of abundance (Appendix C1).

The influence of recruitment on the abundance of Arctic grayling in the Goodpaster River study area is amplified due to the departure of adult Arctic grayling from the study area. A portion of adult (age-4 and up) Arctic grayling either move out of the river itself (Reed 1961; Ridder 1991) or move upstream out of the study area (Tack 1974; 1980). Reed (1961) and Ridder (1991) analyzed data that strongly indicated that the Goodpaster River serves as a spawning and nursery stream for Arctic grayling that oversummer in other places, namely, but not limited to, the Richardson and Delta Clearwater rivers. To carry this hypothesis a step further, abundance of adult Arctic grayling in the Richardson and Delta Clearwater rivers should increase in both

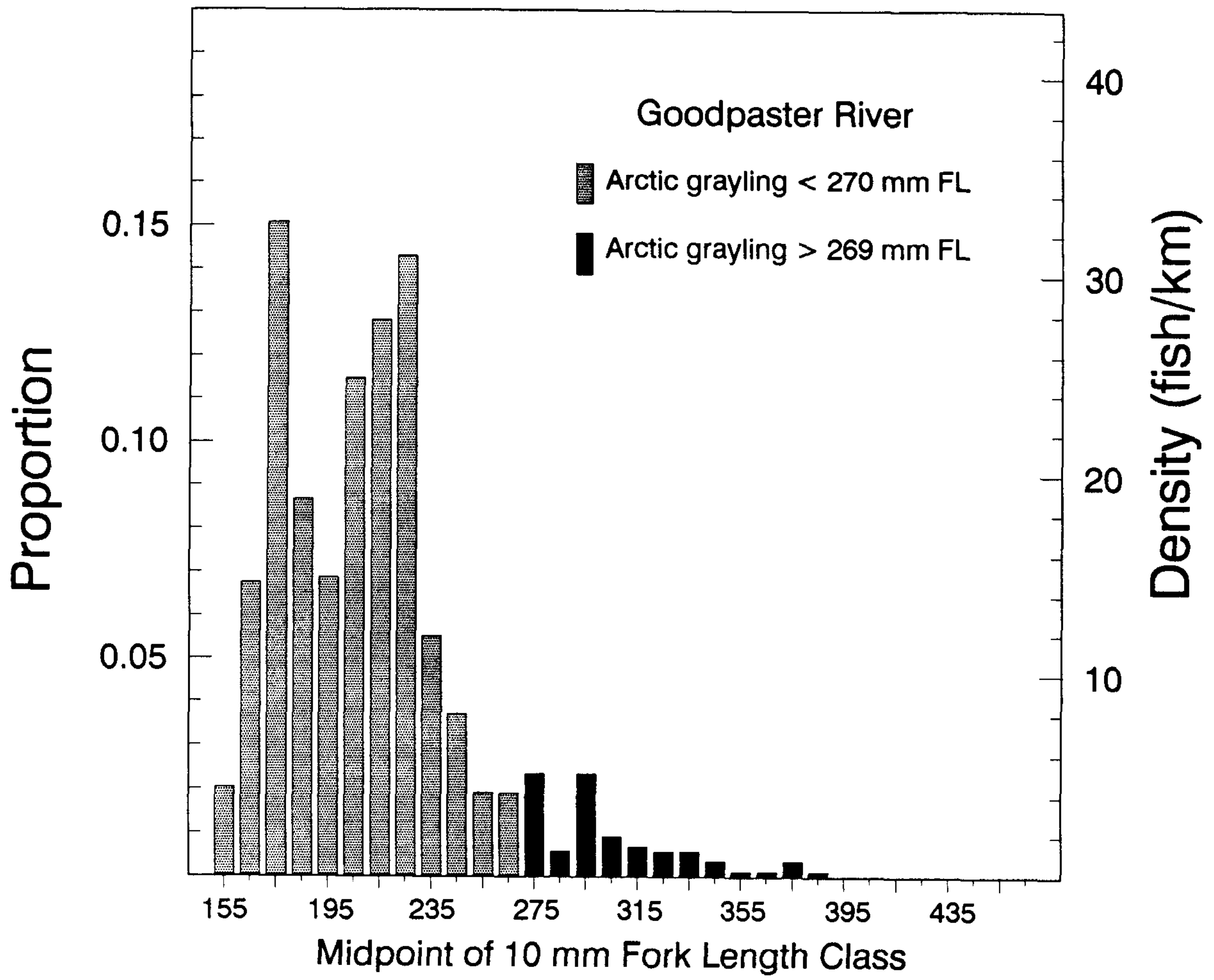

Figure 14. Estimated proportions and densities of Arctic grayling > 149 mm FL by 10 mm length increments within the Goodpaster River study area during August 1993.

Table 11. Estimated abundance (N), standard error of abundance (SE[N]), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age within the Goodpaster River study area (age samples from fish captured during the marking event, 3 - 5 August 1993).

Age Class	N	SE[N]	p	SE[p]
1	-	-	-	-
2	3,585	486	0.33	0.02
3	4,848	635	0.45	0.02
4	1,145	192	0.11	0.01
5	320	82	0.03	0.01
6	724	138	0.07	0.01
7	67	34	0.00	0.00
8	51	28	0.00	0.00
9	34	24	0.00	0.00
10	67	34	0.00	0.00
Totals	10,841	1,340	1.00	-

1994 and 1995 due to the strong age-3 and -4 Arctic grayling estimated within the Goodpaster River study area in 1993.

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APPENDIX A

Historic Data Summaries - Salcha River

Appendix A1. Summary of recreational effort and catch rate estimates for Arctic grayling harvested from the Salcha River, 1953-1958, 1960, 1963-1964, 1968, 1974, and 1987[a].

Year	Interviews	Angler-hours	GR/hr[b]
1953	102	344	0.48
1954	132	646	0.84
1955[c]	174	728	1.09
1956[c]	391	1,659	0.83
1957[c]	86	321	0.78
1958[c]	108	423	1.01
1960	ND	2,600	1.22
1963	275	---	0.67[c]
1964	409	1,816	0.64
1968	2,013[e]	7,035[d]	1.00
1974	827	11,284[d]	0.42
1987	152	---	0.66

[a] Statistics taken from Warner (1959b) for 1953-1958, Reed (1961) for 1960, Roguski and Winslow (1969) for 1963-1968, Kramer (1975) for 1974, and Baker (1988) for 1987.

[b] GR/hr is the number of Arctic grayling harvested per angler-hour.

[c] This catch rate includes salmon (Roguski and Winslow 1969).

[d] Data expanded from sample time/area to the entire fishery.

Appendix A2. Summary of abundance estimates of Arctic grayling in the Salcha River, 1972, 1974, 1985, and 1988-1993[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/2-8/4/72	Redmond Creek	ND	5	503/km	Low
7/10-7/22/74	Redmond Creek to TAPS[d]	ND	ND	765/km	490-5,032/km
7/10-7/22/74	TAPS to 8 km upstream	ND	ND	991/km	690-2,595/km
7/10-7/22/74	TAPS to 8 km downstream	ND	ND	551/km	397-1,174/km
8/5-8/9/85	Flat Creek	205	6	497/km	128-1,064/km
5/24-6/8/88	TAPS to 16 km upstream	208	28	138/km	SE = 34/km
6/12-6/16/89	Richardson Hwy. bridge to 36.8 km upstream	616	55	188/km	SE = 21/km
6/26-6/27/90	Richardson Hwy. bridge to 36.8 km upstream	495	40	157/km	SE = 18/km
6/25-7/2/91	Richardson Hwy. bridge to 36.8 km upstream	439[e] 382	27 27	147/km 114/km	SE = 28/km SE = 25/km
6/15-6/25/92	Richardson Hwy. bridge to 36.8 km upstream	709[f]	52	209/km	SE = 69/km
6/7 -6/17/93	Richardson Hwy. bridge to 36.8 km upstream	1,294	66	433/km	SE = 66/km

a Data sources are: 1972 (Tack 1973); 1974 (Bendock 1974; Kramer 1975); 1985 (Holmes et al. 1986); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (Ridder et al. 1993).

b The 1972-1985 estimates were calculated with the modified Schnabel formula (Ricker 1975). The 1988 through 1990 estimates were calculated with a modified Petersen estimate of Evenson (1988). The 1991 estimate was calculated with modified Petersen (Bailey 1952).

c Confidence is a crude measure of precision (e.g. Low) or the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988-1991 were from bootstrap methods (Efron 1982); a standard error (SE) is reported for these estimates.

d TAPS = Trans-Alaska Pipeline System.

e Mark-recapture experiment results are for Full model (^ 150 mm Fl; upper) and Reduced model (^ 200 mm Fl; lower).

f Mark-recapture results are for the Reduced model (^ 200 mm Fl), due to the lack of recaptures of Arctic grayling < 207 mm.

Appendix A3. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Salcha River, 1985-1993[a].

	1985[b]			1986[c]			1987[d]			1988[e]			1989[f]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	1	0.01	0.01	0	0.00	---	2	<0.01	<0.01	17	0.03	0.01	17	0.03	0.01
3	13	0.06	0.02	19	0.12	0.03	35	0.07	0.01	116	0.20	0.02	155	0.35	0.03
4	3	0.01	0.01	25	0.16	0.03	205	0.40	0.02	83	0.14	0.01	143	0.26	0.02
5	29	0.13	0.02	14	0.09	0.02	120	0.23	0.02	175	0.30	0.02	75	0.13	0.01
6	69	0.32	0.03	37	0.24	0.03	80	0.15	0.02	58	0.10	0.01	74	0.11	0.02
7	58	0.27	0.03	26	0.17	0.03	56	0.11	0.01	54	0.09	0.01	24	0.04	0.01
8	25	0.12	0.02	22	0.14	0.03	15	0.03	0.01	51	0.09	0.01	30	0.05	0.01
9	18	0.08	0.02	8	0.05	0.02	4	0.01	<0.01	22	0.04	0.01	18	0.03	0.01
10	2	0.01	0.01	3	0.02	0.01	2	<0.01	<0.01	4	0.01	<0.01	3	<0.01	<0.01
11	0	0.00	---	1	0.01	0.01	0	0.00	---	1	<0.01	<0.01	0	0.00	---
Totals	218	1.00		154	1.00		519	1.00		581	1.00		539	1.00	

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	1990[g]			1991[h]			1992[i]			1993[k]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	45	0.22	0.03	12	0.04	0.01	1(25)[j]	<0.01	<0.01	42	0.08	0.02
3	76	0.37	0.03	45	0.16	0.02	62(96)	0.15	0.03	193	0.47	0.03
4	38	0.19	0.03	69	0.25	0.03	251(254)	0.48	0.04	116	0.21	0.02
5	18	0.09	0.02	81	0.30	0.03	183	0.25	0.03	114	0.17	0.02
6	13	0.06	0.02	37	0.13	0.02	66	0.07	0.02	53	0.05	0.01
7	7	0.03	0.01	19	0.07	0.01	28	0.03	0.01	11	0.01	0.01
8	5	0.02	0.01	7	0.03	0.01	18	0.02	0.01	4	<0.01	<0.01
9	1	<0.01	<0.01	2	0.01	<0.01	5	0.01	<0.01	0	0.00	0.00
10	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	1	<0.01	<0.01
11	0	0.00	---	1	<0.01	<0.01	0	0.00	----	0	0.00	0.00
Totals	203	1.00	---	274	1.00	---	552	1.00	---	552	1.00	---

[a] Source documents are: 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] Sampling was conducted with an AC electrofishing boat and hook-and-line gear from river km 64.0 to river km 57.6 (5-9 August 1985).

[c] Sampling was conducted with a DC electrofishing boat and hook-and-line gear from river km 112.0 to river km 4.8 (11-15 August 1986).

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[d] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 4.8 (1-9 June 1987).

[e] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 16.0 (24 May through 9 June 1988).

[f] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (12 through 16 June 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[g] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (19 through 27 June 1990).

[h] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (25 June through 2 July, 1991).

[i] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (22 June through 25 June, 1992). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[j] Numbers in parentheses represent the number of fish sampled at age that were ≥ 150 mm FL.

[k] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (7 June through 8 June, 1993). Age composition and standard error are adjusted for differential probability of capture by size of fish in the lower section of the study area.

Appendix A4. Summary of RSD indices of Arctic grayling captured in the Salcha River, 1972, 1974, and 1985-1993[a].

Year		RSD Category[b]			
	Stock	Quality	Preferred	Memorable	Trophy
1972 - Number sampled	ND[c]	ND	ND	ND	ND
RSD	0.53	0.46	<0.01	0	0
SE	ND	ND	ND	---	---
1974 - Number sampled	153	14	2	0	0
RSD	0.91	0.08	0.01	---	---
SE	0.02	0.02	0.01	---	---
1985 - Number sampled	17	155	57	0	0
RSD	0.07	0.68	0.25	---	---
SE	0.02	0.03	0.03	---	---
1986 - Number sampled	47	71	56	0	0
RSD	0.27	0.41	0.32	---	---
SE	0.03	0.04	0.04	---	---
1987 - Number sampled	275	171	71	1	0
RSD	0.53	0.33	0.14	<0.01	---
SE	0.02	0.02	0.02	<0.01	---
1988 - Number sampled	280	217	110	1	0
RSD	0.46	0.36	0.18	<0.01	---
SE	0.02	0.02	0.02	<0.01	---
1989 - Number sampled	755	342	124	2	0
Adjusted RSD[d]	0.71	0.22	0.08	<0.01	---
SE	0.04	0.03	0.01	<0.01	---
1990 - Number sampled	365	95	40	0	0
RSD	0.73	0.19	0.08	---	---
SE	0.02	0.02	0.01	---	---
1991 - Number sampled[e]	170	110	12	0	0
RSD	0.58	0.38	0.04	---	---
SE	0.03	0.03	0.01	---	---

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	RSD Category[b]				
Year	Stock	Quality	Preferred	Memorable	Trophy
1992 - Number sampled[e]	377	290	42	0	0
Adjusted RSD[d]	0.71	0.25	0.04	---	---
SE	0.08	0.07	0.01	---	---
1993 - Number sampled	458	186	24	0	0
Adjusted RSD	0.81	0.16	0.03	---	---
SE	0.03	0.03	0.01	---	---

[a] Data sources: 1972 (Tack 1973); 1974 (Bendock 1974; Kramer 1975); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

[c] ND = data not furnished in original citation.

[d] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

[e] Includes only Arctic grayling ^ 200 mm Fl.

Appendix A5. Summary of mean length at age data collected from Arctic grayling in the Salcha River, 1952, 1974, 1981, and 1985-1993[a].

	1952			1974			1981			1985			1986		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[e]	103	---	6	111	---	20	126	---	---	---	---	---	---	---
2	ND	145	---	88	155	---	25	162	---	1	156	---	---	---	---
3	ND	185	---	61	196	---	11	197	---	13	223	15	19	218	16
4	ND	223	---	26	231	---	9	224	---	3	262	18	25	263	25
5	ND	261	---	16	278	---	7	254	---	29	292	10	14	291	26
6	ND	289	---	3	345	---	5	272	---	69	313	20	37	316	24
7	ND	318	---	---	---	---	8	302	---	58	332	16	26	328	40
8	---	---	---	---	---	---	5	335	---	25	346	15	22	360	30
9	---	---	---	---	---	---	1	353	---	18	378	24	8	372	18
10	---	---	---	---	---	---	---	---	---	2	403	90	3	405	16
11	---	---	---	---	---	---	---	---	---	---	---	---	1	364	---
Totals	32			200			91			219			155		

- continued -

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	1987			1988			1989			1990			1991			1992			1993		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	1	123	---	---	---	---	---	---	---	1	180	---
2	2	138	8	17	174	16	17	176	39	96	182	19	25	167	17	25	166	14	42	181	13
3	35	203	36	116	200	16	155	214	24	220	213	22	112	206	22	96	206	21	193	202	23
4	205	241	20	83	241	20	143	252	28	157	252	25	194	234	25	254	252	23	116	260	28
5	120	275	33	175	280	24	75	273	30	75	283	32	170	264	29	183	280	26	114	290	29
6	80	311	36	58	302	30	74	302	37	49	317	33	67	290	29	65	306	30	53	306	29
7	56	339	30	54	332	32	24	315	38	38	346	31	33	301	39	28	323	34	11	327	19
8	15	356	36	51	348	24	30	341	44	19	370	33	16	320	49	18	344	38	4	360	26
9	4	371	30	22	373	30	18	368	21	6	396	36	6	356	45	5	362	44	---	---	---
10	2	444	20	4	394	19	3	407	40	0	---	---	2	369	7	1	385	---	1	373	---
11	---	---	---	1	463	---	0	---	---	0	---	---	1	358	---	---	---	---	---	---	---
Totals	519			581			539			661			626			674			535		

[a] Data sources: 1952 (Warner 1959b); 1974 (Bendock 1974; Kramer 1975); 1981 (Hallberg 1982); 1985 Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] n is the total number of fish aged.

[c] FL is the estimated mean fork length (mm) at age.

[d] SD is the sample standard deviation of FL.

[e] ND = data not furnished in original citation.

APPENDIX B

Historic Data Summaries - Chatanika River

Appendix B1. Summary of recreational effort and catch rate estimates for Arctic grayling harvested from the Chatanika River, 1953-1958, 1974, and 1987[a].

Year	Interviews	Angler-hours	GR/hr[b]
1953	460	955	0.49
1954	243	529	0.78
1955[c]	69	294	0.13
1956[c]	66	223	0.27
1957[c]	62	177	0.18
1958[c]	68	151	0.76
1974	408	27,250[d]	1.02
1987	30	---	0.02

[a] Statistics taken from Warner (1959b) for 1953-1958, Kramer (1975) for 1974, and Baker (1988) for 1987.
[b] GR/hr is the number of Arctic grayling harvested per angler-hour.
[c] From 1955 through 1958 there was a 305 mm (12 inch) minimum length limit for Arctic grayling on the Chatanika River (Warner 1959b).
[d] Data expanded from sample time/area to the entire fishery.

Appendix B2. Summary of abundance estimates of Arctic grayling in the Chatanika River, 1972, 1981, 1984-1985, 1990-1993[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/10-8/17/72	Elliott Highway Bridge	103	4	305/km	Low
8/24-8/26/81	Elliott Highway Bridge	ND[d]	64	169/km	132-197/km
8/15-8/18/84	Elliott Highway Bridge	ND	32	242/km	172-352/km
8/20-8/23/85	Elliott Highway Bridge	132	20	117/km	82-176/km
8/27-9/7/90	28.8 km section from 7.5 km above the Elliott Highway bridge downstream to Any Creek	857	36	670/km	SE = 111/km
8/12-8/15/91	35.2 km section from 9.6 km above the Elliott Highway bridge downstream to Any Creek	608	58	312/km	SE = 62/km
7/11-7/16; 8/23-8/26; 9/9-9/14/91	73.8 km section from Any Creek to Murphy Dome Road extension	667	25	271/km	SE = 52/km
8/17-8/28/92	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	679	41	271/km	SE = 47/km
	73.8 km section from Any Creek to Murphy Dome Road extension	1,767	224	158/km	SE = 17/km
8/16-8/26/93	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	617	32	252/km	SE = 41/km
	50 km section from Any Creek to 16 km above Murphy Dome Road extension	758	89	89/km	SE = 9/km

a Data sources are: 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

b All estimates except 1990 through 1992 were calculated with the modified Schnabel formula (Ricker 1975). The 1990 estimate was calculated with the modified Petersen estimate of Evenson (1988) and the modified Petersen estimate of Bailey (1951, 1952). The 1991 and 1992 estimates used the modified Petersen estimate of Bailey (1951, 1952).

c Confidence is a crude measure of precision (e.g. Low), the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975), or the standard error.

d ND = data not furnished in original citation.

Appendix B3. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Chatanika River, 1984-1993[a].

	1984[b]			1985[c]			1986[d]			1987[e]			1988[f]			1989[g]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	2	0.04	0.03	131	0.55	0.03	0	0.00	---	11	0.02	0.01	22	0.04	0.01	24	0.09	0.03
3	8	0.14	0.05	5	0.02	0.01	119	0.31	0.02	50	0.09	0.01	44	0.09	0.01	47	0.18	0.04
4	22	0.39	0.07	31	0.13	0.02	16	0.04	0.01	295	0.55	0.02	63	0.12	0.01	31	0.12	0.03
5	17	0.30	0.06	59	0.25	0.03	71	0.18	0.02	32	0.06	0.01	216	0.42	0.02	30	0.08	0.02
6	5	0.09	0.04	12	0.05	0.01	119	0.31	0.02	47	0.09	0.01	48	0.09	0.01	88	0.23	0.04
7	1	0.02	0.02	0	0.00	---	47	0.12	0.02	106	0.19	0.02	55	0.11	0.01	54	0.14	0.03
8	1	0.02	0.02	0	0.00	---	12	0.03	0.01	8	0.01	0.01	61	0.12	0.01	47	0.12	0.03
9	0	0.00	---	0	0.00	---	2	0.01	0.00	3	0.01	<0.01	5	0.01	<0.01	15	0.04	0.01
10	0	0.00	---	0	0.00	---	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	2	0.01	<0.01
Totals	56	1.00		238	1.00		386	1.00		553	1.00		515	1.00		338	1.00	

- continued -

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	1990[h]			1991[i]			1992[j]			1993[k]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	126	0.20	0.02	26	0.05	0.01	56	0.14	0.03	88	0.15	0.02
3	347	0.55	0.02	88	0.17	0.02	32	0.08	0.01	123	0.21	0.02
4	80	0.11	0.01	226	0.44	0.02	83	0.22	0.03	26	0.04	0.01
5	45	0.04	0.01	46	0.09	0.01	198	0.36	0.03	100	0.16	0.02
6	51	0.04	0.01	36	0.07	0.01	81	0.11	0.01	162	0.25	0.02
7	57	0.04	0.01	47	0.09	0.01	30	0.03	0.01	57	0.08	0.02
8	17	0.01	<0.01	29	0.06	0.01	39	0.04	0.01	27	0.04	0.01
9	11	0.01	<0.01	12	0.02	0.01	28	0.03	0.01	20	0.03	0.01
10	2	<0.01	<0.01	4	0.01	<0.01	10	0.01	<0.01	17	0.02	0.01
11	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01	10	0.01	0.01
12	---	---	---	---	---	---	---	---	---	7	0.01	0.01
13	---	---	---	---	---	---	---	---	---	1	<0.01	<0.01
Totals	736	1.00		515	1.00		558	1.00		668	1.00	

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Appendix B3. (Page 3 of 3).

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[a] Source documents are: 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] Sampling was conducted with an AC electrofishing boat near the Elliott Highway bridge (15-18 August 1984).

[c] Sampling was conducted with an AC electrofishing boat near the Elliott Highway bridge (20-23 August 1985).

[d] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (4-28 August 1986).

[e] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (10-13 August 1987).

[f] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (15-26 August and 7-20 September 1988).

[g] Sampling was conducted with a DC electrofishing boat downstream of the Elliott Highway bridge (12 through 28 September 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[h] Sampling was conducted with a DC electrofishing boat in a 28.8 km section, beginning 7.5 km upstream of the Elliott Highway bridge and ending 21.3 km downstream of the bridge (27 August through 7 September 1990). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[i] Sampling was conducted with a DC electrofishing boat in a 35.2 km section, beginning 9.6 km upstream of the Elliott Highway bridge and ending 25.6 km downstream of the bridge (5 through 7 August 1991).

[j] Sampling was conducted with a DC electrofishing boat in a 101 km section, beginning 3.2 km upstream of the Elliott Highway bridge and ending downstream at the Murphy Dome Road terminus (24 through 28 August 1992). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[k] Sampling was conducted with a DC electrofishing boat in a 78.2 km section, beginning 3.2 km above the Elliott Highway bridge and ending downstream 24 km above Murphy Dome Road extension (23 through 26 August 1993).

Appendix B4. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1993.

	1952			1953			1981			1982			1984			1985		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND	94	---	19	96	---	0	---	---	5	95	---	16	101	---	0	---	---
2	ND	133	---	77	144	---	4	169	---	29	135	---	3	149	---	131	147	15
3	ND	176	---	129	190	---	7	204	---	22	187	---	8	172	---	5	181	25
4	ND	212	---	28	207	---	10	233	---	23	216	---	22	196	---	31	212	22
5	ND	243	---	4	226	---	7	264	---	5	236	---	17	225	---	59	233	24
6	---	---	---	9	254	---	3	286	---	2	280	---	5	251	---	12	268	18
7	---	---	---	---	---	---	1	290	---	1	252	---	1	258	---	---	---	---
8	---	---	---	---	---	---	---	---	---	1	334	---	1	301	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Totals	149			266			32			88			73			238		

- continued -

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Age Class	1986			1987			1988			1989			1990			1991		
	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	4	125	16	19	125	10	---	---	---
2	---	---	---	11	157	15	22	170	13	30	159	27	143	167	14	26	165	9
3	119	195	21	50	200	24	44	205	16	47	203	38	351	195	17	87	204	22
4	16	231	36	295	228	18	63	238	21	31	234	42	80	242	18	227	227	21
5	71	248	16	32	265	22	216	259	22	30	267	56	45	269	15	46	264	27
6	119	267	20	47	273	21	48	278	24	88	286	36	52	282	19	36	285	17
7	47	292	28	106	288	30	55	298	22	54	305	46	61	297	22	48	300	29
8	12	304	21	8	319	18	61	312	25	47	313	49	17	324	23	29	314	29
9	2	283	35	3	296	55	5	328	8	15	334	86	11	329	12	12	317	40
10	---	---	---	1	325	___	1	352	---	2	337	147	2	337	34	3	334	6
Totals	386			553			515			349			781			514		

- continued -

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	1992			1993		
Age Class	n	FL	SD	n	FL	SD
1	---	---	---	1	195	---
2	56	175	22	88	172	17
3	32	213	24	123	204	22
4	83	248	26	26	243	23
5	198	262	24	100	270	23
6	81	289	21	162	284	21
7	30	310	22	57	300	19
8	39	320	16	27	317	17
9	28	337	24	20	322	23
10	10	329	21	17	334	12
11	1	350	---	10	345	20
12	---	---	---	7	344	10
13	---	---	---	1	362	---

[a] Data sources: 1952-1953 (Warner 1959b); 1981 (Hallberg 1982); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] n is the total number of fish aged.

[c] FL is the mean fork length (mm) at age.

[d] SD is the standard deviation of FL.

Appendix B5. Summary of RSD indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1993[a].

Year		RSD Category[b]			
	Stock	Quality	Preferred	Memorable	Trophy
<u>1952</u> - Number sampled	95	1	0	0	0
RSD	0.99	0.01	---	---	---
SE	0.01	0.01	---	---	---
<u>1953</u> - Number sampled	98	8	0	0	0
RSD	0.92	0.08	---	---	---
SE	0.03	0.03	---	---	---
<u>1954</u> - Number sampled	42	1	0	0	0
RSD	0.98	0.02	---	---	---
SE	0.02	0.02	---	---	---
<u>1972</u> - Number sampled	121	0	0	0	0
RSD	1.00	---	---	---	---
SE	---	---	---	---	---
<u>1982</u> - Number sampled	53	3	0	0	0
RSD	0.95	0.05	---	---	---
SE	0.03	0.03	---	---	---
<u>1984</u> - Number sampled	206	9	1	0	0
RSD	0.95	0.04	0.01	---	---
SE	0.01	0.01	0.01	---	---
<u>1985</u> - Number sampled	146	11	0	0	0
RSD	0.93	0.07	---	---	---
SE	0.02	0.02	---	---	---
<u>1986</u> - Number sampled	279	121	4	0	0
RSD	0.69	0.30	0.01	---	---
SE	0.02	0.02	0.01	---	---
<u>1987</u> - Number sampled	420	126	7	0	0
RSD	0.76	0.23	0.01	---	---
SE	0.02	0.02	0.01	---	---
<u>1988</u> - Number sampled	361	221	13	0	0
RSD	0.61	0.37	0.02	---	---
SE	0.02	0.02	0.01	---	---

- continued -

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RSD Category[b] Year		Stock	Quality	Preferred	Memorable	Trophy
1989 -	Number sampled	150	221	4	0	0
	RSD[c]	0.49	0.49	0.02	---	---
	SE	0.06	0.06	0.01	---	---
1990 -	Number sampled	1,201	309	19	0	0
	RSD[c]	0.90	0.09	0.01	---	---
	SE	0.02	0.02	<0.01	---	---
1991[d]-	Number sampled	516	222	25	0	0
	RSD[c]	0.84	0.14	0.02	---	---
	SE	0.03	0.03	<0.01	---	---
1991[e]-	Number sampled	381	312	56	0	0
	RSD	0.51	0.42	0.07	---	---
	SE	0.02	0.02	0.01	---	---
1992[f]-	Number sampled	294	134	9	0	0
	RSD[c]	0.84	0.15	0.01	---	---
	SE	0.03	0.03	<0.01	---	---
1992[g]-	Number sampled	1,250	1,507	175	0	0
	RSD[c]	0.44	0.50	0.06	---	---
	SE	0.01	0.01	<0.01	---	---
1993[d]-	Number sampled	226	155	9	0	0
	RSD[c]	0.58	0.40	0.02	---	---
	SE	0.03	0.03	<0.01	---	---
1993[h]-	Number sampled	215	279	34	0	0
	RSD[c]	0.41	0.53	0.06	---	---
	SE	0.02	0.02	0.01	---	---

a Source documents are: 1952-1958 (Warner 1959b); 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

b Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 169 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

c RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

d 28.8 km section from 3.2 km above the Elliott Highway bridge downstream to below Any Creek.

e 83.2 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

f 35.2 km section from 9.6 km above the Elliott Highway bridge downstream to below Any Creek.

g 73.8 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

h 50 km section from 25.6 km below the Elliott Highway bridge to 24 km above Murphy Dome Extension Rd.

Appendix B6. Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Salcha and Chatanika rivers, 1986-1988[b].

	Salcha River		Chatanika River	
Parameter	Estimate	Standard Error	Estimate	Standard Error
L_∞[c]	489	19	375	11
K[d]	0.16	0.02	0.19	0.02
t_0[e]	-0.42	0.16	-1.01	0.20
$Corr(L_\infty,K)$[f]	-0.99	---	-0.98	---
$Corr(L_\infty,t_0)$	-0.88	---	-0.89	---
$Corr(K,t_0)$	0.94	---	0.96	---
Sample size	1,198		1,469	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_0)))$. The parameters of this model were estimated with data collected during 1986 through 1988. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth were age 1 through age 11 for the Salcha River, and age 1 through age 10 for the Chatanika River.

[b] Source citation is Clark (1988).

[c] L_∞ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[d] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[e] t_0 represents the hypothetical age at which a fish would have zero length (Ricker 1975).

[f] $Corr(x,y)$ is the correlation of parameter estimates x and y.

APPENDIX C

Historic Data Summaries - Goodpaster River

Appendix C1. Summary of abundance estimates of Arctic grayling (≥ 150 mm FL) in the Goodpaster River, 1972 - 1993[a].

						Fish/km[b]	
Year	Day/Month	River km	M	C	R	N	95% CI[c] or (SE)
1972	12-14 Jul	4.8 - 9.6	210	---	30	189	---
1973	1 Jun-30 Aug	0 - 53	2,328	1,734	122	480	411 - 590
		53 - 98	561	680	16	322	223 - 732
		98 - 184	415	410	19	81	57 - 164
		0 - 184	---	---	---	241	209 - 287
1974[d]	15-29 Jul	0 - 53	1,217	489	55	201	155 - 260
		53 - 98	479	279	9	298	165 - 596
		98 - 184	343	275	27	63	44 - 93
		0 - 184	---	---	---	152	124 - 186
1975	23-27 Jun	4.8 - 9.6	330	145	31	314	223 - 456
		24 - 28.8	317	319	34	604	436 - 863
		combined	647	464	65	475	374 - 603
1976	21-24 Jun	4.8 - 9.6	155	99	9	323	178 - 646
		24 - 28.8	202	165	18	368	238 - 597
		combined	357	264	27	351	245 - 524
1977	21-24 Jun	4.8 - 9.6	234	150	11	613	356-1,150
		24 - 28.8	396	263	60	357	278 - 457
		combined	630	413	71	377	300 - 474
1978	20-23 Jun	4.8 - 9.6	248	167	19	434	284 - 694
		24 - 28.8	373	212	32	502	359 - 726
		combined	621	379	51	473	361 - 618
1980	24-27 Jun	4.8 - 9.6	231	153	13	529	318 - 938
		24 - 28.8	337	213	31	470	334 - 683
		combined	568	366	44	483	362 - 658
1982	29 Jun-2 Jul	4.8 - 9.6	79	107	9	178	98 - 356
		24 - 28.8	214	155	39	174	128 - 242
		combined	293	260	48	163	123 - 219
1984	27-29 Jun	4.8 - 9.6	265	91	12	391	153 - 629
		24 - 28.8	216	169	28	264	161 - 367
		combined	481	260	40	352	249 - 455

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Year	Day/Month	River km	M	C	R	Fish/km N	Fish/km 95% CI or (SE)
1985	25-27 Jun	4.8 - 9.6	189	213	7	459	238 - 966
1985	6-13 Aug	4.8 - 9.6	307	455	42	400	296 - 554
		24 - 28.8	303	424	45	328	245 - 450
		combined	610	879	87	364	271 - 502
1986	11-15 Aug	4.8 - 9.6	230	312	15	403	250 - 686
		24 - 28.8	293	389	42	256	193 - 352
		combined	523	701	57	305	234 - 397
1987	4-10 Aug	4.8 - 9.6	138	191	14	188	115 - 324
		24 - 28.8	158	213	24	133	91 - 203
		combined	274	363	35	134	97 - 191
1988	8-18 Aug	4.8 - 53	1,130	1,002	139	158	(12)
1989	8-17 Aug	3 - 53	955	984	124	161	(15)
1990	8-16 Aug	3 - 53	1,051	554	82	145	(15)
1991	7-14 Aug	3 - 53	780	429	42	157	(17)
1992	4-14 Aug	3 - 53	922	562	80	138	(16)
1993	3-13 Aug	3 - 53	730	890	59	219	(27)

[a] Data sources: 1972 - 1974 (Tack 1973, 1974, 1975); 1975 - 1978 and 1980 (Peckham 1976, 1977, 1978, 1979, 1981); 1982 and 1984 (Ridder 1983, 1985); 1985 (Holmes et al. 1986); 1986 - 1987 (Clark and Ridder 1987, 1988; Ridder 1989); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] Schnabel estimator in 1972, 1973, 1985 through 1987; modified Petersen (Bailey 1951, 1952) estimator in 1974 through 1984 and 1992; modified Petersen (Evenson 1988) in 1988; bootstrapped modified Petersen (Bailey 1951, 1952) in 1989, 1990, and 1991.

[c] The confidence interval is based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988 through 1991 were from bootstrap methods (Efron 1982) and a standard error (SE) is reported.

[d] Estimate was based on total marks in 1973 which were adjusted with a mortality rate of 0.46 (Tack 1975). Number of marks presented shown for 1973 do not include those applied during the final 1973 sampling event.

Appendix C2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1993[a].

	1955 29 July - 15 Sept.			1956 summer			1957 11 June - 15 Aug.			1958 7 May - 25 July			1969		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	14	0.08	0.02	15	0.05	0.01	3	0.01	<0.01	111	0.10	0.01	0	---	---
2	49	0.27	0.03	109	0.37	0.03	40	0.10	0.02	532	0.48	0.02	9	0.13	0.04
3	40	0.22	0.03	115	0.39	0.03	178	0.44	0.03	106	0.10	0.01	13	0.19	0.05
4	53	0.29	0.03	30	0.10	0.02	122	0.30	0.02	225	0.20	0.01	12	0.17	0.05
5	14	0.08	0.02	19	0.06	0.01	30	0.07	0.01	100	0.09	0.01	11	0.16	0.04
6	6	0.03	0.01	5	0.02	0.01	19	0.05	0.01	16	0.01	<0.01	9	0.13	0.04
7	5	0.03	0.01	4	0.01	0.01	6	0.02	0.01	10	0.01	<0.01	4	0.06	0.03
8	0	---	---	0	---	---	5	0.01	0.01	4	<0.01	<0.01	7	0.10	0.04
9	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	4	0.06	0.03
10	0	---	---	0	---	---	0	---	---	0	---	---	1	0.01	0.01
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	181	1.00		297	1.00		404	1.00		1104	1.00		70	1.00	

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	1973[e] 15 June - 15 Aug.			1975 23 June - 24 June			1976 21 June - 22 June			1977 21 June - 22 June			1978 21 June - 22 June		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	3	0.03	0.02	1	0.01	0.01	8	0.07	0.02	2	0.02	0.01
2	3	0.03	0.02	3	0.03	0.02	13	0.11	0.03	1	0.01	0.01	23	0.22	0.04
3	65	0.65	0.05	52	0.52	0.05	13	0.11	0.03	76	0.66	0.04	13	0.13	0.03
4	27	0.27	0.05	7	0.07	0.03	44	0.37	0.04	6	0.05	0.02	58	0.56	0.05
5	2	0.02	0.01	29	0.29	0.05	25	0.21	0.04	13	0.11	0.03	8	0.08	0.03
6	3	0.03	0.02	5	0.05	0.02	22	0.18	0.03	12	0.10	0.03	0	---	---
7	0	---	---	1	0.01	0.01	1	0.01	0.01	0	---	---	0	---	---
8	0	---	---	0	---	---	1	0.01	0.01	0	---	---	0	---	---
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	100	1.00		100	1.00		120	1.00		116	1.00		104	1.00	

- continued -

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	1980 24 June - 25 June			1982 29 June - 2 July			1984 27 June - 28 June			1985[e] 25 June - 26 June			1985[e] 8 - 11 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	5	0.05	0.02	0	---	---	7	0.07	0.03	0	---	---	0	---	---
2	26	0.27	0.05	8	0.08	0.03	7	0.07	0.03	3	0.02	0.01	56	0.27	0.03
3	19	0.20	0.04	21	0.22	0.04	17	0.17	0.04	44	0.22	0.03	27	0.13	0.02
4	40	0.42	0.05	43	0.44	0.05	48	0.48	0.05	33	0.16	0.03	22	0.11	0.02
5	6	0.06	0.03	21	0.22	0.04	11	0.11	0.03	79	0.39	0.03	69	0.33	0.03
6	0	---	---	4	0.04	0.02	7	0.07	0.03	25	0.12	0.02	18	0.09	0.02
7	0	---	---	0	---	---	3	0.03	0.02	16	0.08	0.02	15	0.07	0.02
8	0	---	---	0	---	---	0	---	---	4	0.02	0.01	1	0.01	0.01
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	96	1.00		97	1.00		100	1.00		204	1.00		208	1.00	

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	1986[e] 11 - 15 August			1987[e] 3 - 10 August			1988[e] 8 - 11 August			1989[e] 8 - 10 August			1990[e] 8 - 10 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p[f]	SE[f]	n	p[f]	SE[f]
1	0	---	---	6	0.02	0.01	1	<0.01	<0.01	0	---	---	46	0.05	<0.01
2	80	0.14	0.02	55	0.15	0.02	144	0.18	0.01	364	0.47	0.02	79	0.08	<0.01
3	360	0.63	0.02	51	0.14	0.02	58	0.07	0.01	165	0.21	0.01	562	0.59	0.01
4	26	0.05	0.01	165	0.46	0.03	86	0.11	0.01	37	0.04	0.01	94	0.10	<0.01
5	37	0.07	0.01	9	0.03	0.01	317	0.40	0.02	104	0.09	0.01	36	0.04	<0.01
6	56	0.10	0.01	22	0.06	0.01	34	0.04	0.01	134	0.11	0.02	55	0.05	<0.01
7	8	0.01	0.01	32	0.09	0.02	67	0.09	0.01	44	0.03	<0.01	60	0.06	0.01
8	2	<0.01	<0.01	12	0.03	0.01	45	0.06	0.01	29	0.02	0.01	13	0.01	<0.01
9	2	<0.01	<0.01	5	0.01	0.01	20	0.03	0.01	7	0.01	<0.01	8	0.01	<0.01
10	0	---	---	1	<0.01	<0.01	8	0.01	<0.01	4	<0.01	<0.01	4	<0.01	<0.01
11	0	---	---	0	---	---	3	<0.01	<0.01	1	<0.01	0.00	0	---	---
12	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	0	---	---
Total	571	1.00		358	1.00		784	1.00		889	1.00		957	1.00	

- continued -

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Age Class	1991[e] 7 - 9 August n	p	SE	1992[e] 4 - 6 August n	p	SE	1993[e] 3 - 5 August n	p	SE
1	8	0.01	<0.01	1	0.01	<0.01	0	---	---
2	393	0.53	0.02	319	0.39	0.02	213	0.33	0.02
3	72	0.10	0.02	199	0.24	0.02	288	0.45	0.02
4	186	0.25	0.02	81	0.10	0.02	68	0.11	0.01
5	27	0.04	0.01	179	0.22	0.02	19	0.03	0.01
6	18	0.02	<0.01	23	0.03	0.02	43	0.07	0.01
7	27	0.03	0.01	12	0.01	<0.01	4	0.01	<0.01
8	13	0.02	0.01	9	0.01	<0.01	3	<0.01	<0.01
9	5	0.01	<0.01	1	<0.01	<0.01	2	<0.01	<0.01
10	2	<0.01	<0.01	3	<0.01	<0.01	4	0.01	<0.01
11	0	---	---	1	<0.01	<0.01	0	---	---
12	0	---	---	0	---	---	0	---	---
Total	751	1.00		828	1.00		644	1.00	

[a] Data sources and gear type: 1955 - 1956 (hook and line (H&L); Warner 1957); 1957 (H&L; Warner 1958); 1958 (seine; Warner 1959a); 1969 (electrofishing boat (EB); Roguski and Tack 1970); 1973 - 1974 (EB; Tack 1973; 1974); 1975 - 1980 (EB; Peckham 1976; 1977; 1978; 1979; 1980; 1981); 1982 - 1984 (EB; Ridder 1983; 1985); 1985 (EB; Holmes et al. 1986); 1986 - 1987 (EB; Clark and Ridder 1987; 1988); 1988 (EB, Ridder 1989); 1989 (EB; Clark and Ridder 1990); 1990 (EB; Clark et al. 1991); 1991 (EB; Fleming et al. 1992); 1992 (EB; Ridder et al. 1993); and, 1993 (EB; this report).

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] For Arctic grayling greater than 149 mm FL only.

[f] Proportions and SE were adjusted to compensate for length bias found in the electrofishing sample.

Appendix C3. Summary of age composition estimates and standard errors for Arctic grayling sampled in the middle (53-98 km) and upper (98 - 152 km) sections of the Goodpaster River, summer, 1973 and 1979[a].

	1973[b] 15 June - 15 Aug middle			1973[b] 15 June - 15 Aug upper			1979 23 - 24 June upper		
Age Class	n[c]	p[d]	SE[e]	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---
2	3	0.03	0.02	0	---	---	0	---	---
3	26	0.26	0.04	0	---	---	0	---	---
4	30	0.30	0.05	11	0.11	0.03	0	---	---
5	31	0.31	0.05	15	0.15	0.04	6	0.10	0.04
6	8	0.08	0.03	17	0.17	0.04	11	0.18	0.05
7	2	0.02	0.01	35	0.36	0.05	23	0.37	0.06
8	0	---	---	6	0.06	0.02	18	0.29	0.06
9	0	---	---	7	0.07	0.03	5	0.08	0.03
10	0	---	---	4	0.04	0.02	0	---	---
11	0	---	---	2	0.02	0.02	0	---	---
12	0	---	---	1	0.01	0.01	0	---	---
Total	100	1.00		98	1.00		63	1.00	

[a] Data sources and gear type: 1973 (middle section - electrofishing boat; upper section - hook and line; Tack 1973; 1974); 1979 (hook and line, Peckham 1979).

[b] For Arctic grayling greater than 149 mm FL only.

[c] n = sample size.

[d] p = proportion.

[e] SE = standard error of the proportion.

Appendix C4. Age composition estimates[a] for Arctic grayling weighted by three area population densities, Goodpaster River, 1973 and 1974.

	1973			1974		
Age Class	n[b]	p[c]	SE[d]	n	p	SE
2	ND[e]	0.03	ND	---	---	---
3	ND	0.45	ND	ND	0.07	ND
4	ND	0.28	ND	ND	0.52	ND
5	ND	0.13	ND	ND	0.20	ND
6	ND	0.05	ND	ND	0.06	ND
7	ND	0.04	ND	ND	0.06	ND
8	ND	0.01	ND	ND	0.01	ND
9	ND	0.01	ND	ND	<0.01	ND
10	ND	<0.01	ND	ND	<0.01	ND
11	ND	<0.01	ND	---	---	---
12	ND	<0.01	ND	---	---	---
Total	ND	1.00		277	1.00	

[a] Estimates developed from combining age proportions found in three river sections using the estimated abundance in each section as a weighting factor. Data source is Tack (1974, 1975).

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] ND = no data in citation.

Appendix C5. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE
1	2	0.01	0.01	0	---	---	0	---	---	0	---	---
2	4	0.02	0.01	0	---	---	9	0.03	0.01	4	0.01	0.01
3	26	0.12	0.02	11	0.03	0.01	67	0.20	0.02	2	0.01	0.01
4	30	0.14	0.02	32	0.08	0.01	31	0.09	0.02	49	0.16	0.02
5	29	0.13	0.02	136	0.35	0.02	34	0.10	0.02	11	0.04	0.01
6	45	0.20	0.03	53	0.14	0.02	92	0.28	0.02	28	0.09	0.02
7	29	0.13	0.02	85	0.22	0.02	48	0.14	0.02	72	0.24	0.03
8	33	0.15	0.02	25	0.06	0.01	32	0.10	0.02	53	0.18	0.02
9	16	0.07	0.02	31	0.08	0.01	10	0.03	0.01	45	0.15	0.02
10	7	0.03	0.01	10	0.03	0.01	5	0.02	0.01	16	0.05	0.01
11	1	0.01	<0.01	7	0.02	0.01	2	0.01	<0.01	15	0.05	0.01
12	0	---	---	0	---	---	3	0.01	0.01	3	0.01	0.01
13	0	---	---	0	---	---	2	0.01	<0.01	2	0.01	0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01
Total	222	1.00		390	1.00		335	1.00		301	1.00	

a All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.

b n = sample size.

c p = proportion.

d SE = standard error of the proportion.

Appendix C6. Summary of age composition estimates and standard errors for adult Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
5	14	0.10	0.03	3	0.02	0.01	1	0.01	0.01	2	0.01	0.01	20	0.03	0.01
6	41	0.29	0.04	25	0.16	0.03	43	0.31	0.04	22	0.10	0.02	131	0.20	0.02
7	29	0.21	0.03	62	0.39	0.04	43	0.31	0.04	68	0.30	0.03	202	0.30	0.02
8	33	0.23	0.04	23	0.14	0.03	32	0.23	0.04	52	0.23	0.03	140	0.21	0.02
9	16	0.11	0.03	31	0.19	0.03	10	0.07	0.02	45	0.20	0.03	102	0.15	0.01
10	7	0.05	0.02	10	0.06	0.02	5	0.04	0.02	16	0.07	0.02	38	0.06	0.01
11	1	0.01	0.01	7	0.04	0.02	2	0.01	0.01	15	0.07	0.02	25	0.04	0.01
12	0	---	---	0	---	---	3	0.02	0.01	3	0.01	0.01	6	0.01	<0.01
13	0	---	---	0	---	---	2	0.01	0.01	2	0.01	0.01	4	0.01	<0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01
Total	141	1.00		161	1.00		141	1.00		226	1.00		669	1.00	

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

Appendix C7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1993[a].

	1969 summer			1973 15 June-15 August			1975 23-24 June			1976 21-22 June			1977 21-22 June		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	3	82	ND	1	108	ND	8	98	ND
2	9	126	ND[e]	3	146	ND	3	149	ND	13	149	ND	1	151	ND
3	13	171	ND	91	181	ND	52	182	ND	13	187	ND	76	175	ND
4	12	215	ND	68	224	ND	7	207	ND	44	209	ND	6	229	ND
5	11	265	ND	48	276	ND	29	233	ND	25	240	ND	13	245	ND
6	9	297	ND	28	317	ND	5	269	ND	22	264	ND	12	273	ND
7	4	330	ND	37	343	ND	1	346	ND	1	285	ND	0	---	---
8	7	351	ND	6	368	ND	0	---	---	1	364	ND	0	---	---
9	4	362	ND	7	396	ND	0	---	---	0	---	---	0	---	---
10	1	378	ND	4	404	ND	0	---	---	0	---	---	0	---	---
11	0	---	---	3	417	ND	0	---	---	0	---	---	0	---	---
12	0	---	---	1	432	ND	0	---	---	0	---	---	0	---	---
Total	70			295			100			120			116		

- continued -

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	1978	21-22 June		1979	25-28 June		1980	24-25 June		1982	29-30 June		1984	27-28 June	
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	2	101	ND	0	---	---	5	105	ND	0	---	---	7	92	ND
2	23	140	ND	0	---	---	26	156	ND	8	133	ND	7	161	ND
3	13	186	ND	0	---	---	19	202	ND	21	191	ND	17	204	ND
4	58	208	ND	0	---	---	40	220	ND	43	218	ND	48	219	ND
5	8	268	ND	6	281	ND	6	260	ND	21	249	ND	11	259	ND
6	0	---	---	11	320	ND	0	---	---	4	270	ND	7	258	ND
7	0	---	---	23	359	ND	0	---	---	0	---	---	3	289	ND
8	0	---	---	18	379	ND	0	---	---	0	---	---	0	---	---
9	0	---	---	5	395	ND	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	104			63			96			97			100		

- continued -

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	1985[f] 25-26 June			1985[f] 6-8 August			1986[f] 11-15 August			1987[f] 3-10 August			1988[f] 8-11 August			1989[f] 8-10 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	6	166	17	1	155	---	0	---	---
2	3	160	6	56	164	15	80	164	9	55	183	15	144	187	13	364	171	11
3	44	190	12	27	208	10	360	193	19	51	206	14	58	221	14	165	220	14
4	33	224	14	22	236	14	26	235	15	165	233	13	86	243	16	37	253	17
5	79	245	19	69	253	17	37	261	12	9	264	15	317	268	17	104	277	19
6	25	269	20	18	284	13	56	281	22	22	276	14	34	296	17	134	296	18
7	16	284	21	15	292	20	8	305	23	32	288	17	67	307	20	44	315	19
8	4	323	25	1	295	---	2	301	8	12	296	17	45	321	22	29	332	17
9	0	---	---	0	---	---	2	387	27	5	341	34	20	336	33	7	354	19
10	0	---	---	0	---	---	0	---	---	1	311	---	8	352	15	4	384	21
11	0	---	---	0	---	---	0	---	---	0	---	---	3	376	33	1	378	---
12	0	---	---	0	---	---	0	---	---	0	---	---	1	391	---	0	---	---
Total	204	236	37	208	227	47	571	211	72	358	233	38	784	254	46	889	230	59

- continued -

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	1990[f] 8-10 August			1991[f] 7-9 August			1992[f] 4-6 August			1993[f] 3-5 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	46	156	5	8	163	12	1	152	---	0	---	---
2	79	182	11	393	189	11	319	176	12	213	176	11
3	562	214	15	72	217	14	199	224	17	288	214	15
4	94	252	20	186	245	15	81	256	17	68	252	19
5	36	278	23	27	276	14	179	273	15	19	281	19
6	55	297	26	18	294	21	23	308	24	43	295	24
7	60	311	24	27	313	18	12	318	28	4	275	35
8	13	321	28	13	328	27	9	339	26	3	313	12
9	8	345	18	5	348	19	1	318	---	2	350	8
10	4	365	57	2	386	4	3	383	6	4	351	10
11	0	---	---	0	---	---	1	392	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---
Total	957	228	45	751	220	43	828	225	48	828	225	48

[a] Data sources and gear type: 1969 (electrofishing boat (EB); Roguski and Tack 1970); 1973 - 1974 (EB; Tack 1973; 1974); 1975 - 1980 (EB; Peckham 1976; 1977; 1978; 1979; 1980; 1981); 1982 - 1984 (EB; Ridder 1983; 1985); 1985 (EB; Holmes et al. 1986); 1986 - 1987 (EB; Clark and Ridder 1987; 1988); 1988 (EB; Ridder 1989); 1989 (EB; Clark and Ridder 1990); 1990 (EB; Clark et al. 1991); 1991 (EB; Fleming et al. 1992); 1992 (EB; Ridder et al. 1993); and, 1993 (EB; this report).

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

[e] ND = no data in citation.

[f] For Arctic grayling greater than 149 mm FL only.

Appendix C8. Summary of mean length at age data for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD
1	2	96	11	0	---	---	0	---	---	0	---	---
2	4	137	21	0	---	---	9	133	23	4	183	12
3	26	195	9	11	193	9	67	175	20	2	160	10
4	30	217	10	32	224	15	31	221	15	49	224	21
5	29	262	20	136	250	21	34	252	16	11	280	21
6	45	293	31	53	279	17	92	276	21	28	303	21
7	29	311	36	85	301	28	48	305	18	72	328	22
8	33	337	29	25	323	21	32	317	22	53	338	27
9	16	349	24	31	355	23	10	378	25	45	363	21
10	7	368	24	10	365	28	5	385	25	16	379	23
11	1	383	---	7	381	16	2	405	24	15	393	20
12	0	---	---	0	---	---	3	414	26	3	418	10
13	0	---	---	0	---	---	2	416	14	2	371	4
14	0	---	---	0	---	---	0	---	--	1	472	---
Total	222	278	63	390	280	48	335	259	64	301	320	59

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.
[b] n = sample size.
[c] FL = mean fork length (mm) at age.
[d] SD = sample standard deviation of FL.

Appendix C9. Summary of mean length at age data for adult male Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 16 - 17 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	8	276	11	2	304	49	0	---	---	1	339	---	11	286	30
6	21	298	35	7	291	17	21	292	19	15	308	24	64	297	27
7	16	311	42	19	321	30	19	313	17	49	332	22	103	323	28
8	26	337	30	5	329	13	14	318	18	36	344	28	81	336	28
9	11	351	24	11	360	21	4	361	22	37	364	21	63	361	22
10	7	368	24	4	379	35	4	385	23	12	383	25	27	379	27
11	1	383	---	2	394	7	2	405	24	12	390	20	17	391	20
12	0	---	---	0	---	---	3	414	26	3	418	10	6	416	20
13	0	---	---	0	---	---	2	416	14	2	371	4	4	393	25
14	0	---	---	0	---	---	0	---	---	1	472	---	1	472	---
Total	90	322	41	50	333	39	69	325	42	168	350	36	377	337	41

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix C10. Summary of mean length at age data for adult female Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	6	280	11	1	248	---	1	253	---	1	296	---	9	275	17
6	20	296	24	18	283	18	22	287	22	7	298	9	67	290	21
7	13	310	25	43	301	26	24	302	16	19	320	19	99	306	24
8	7	334	23	18	322	23	18	317	24	16	326	19	59	323	23
9	5	345	25	20	352	24	6	344	24	8	360	22	39	351	24
10	0	---	---	6	356	17	1	351	---	4	367	13	11	360	16
11	0	---	---	5	376	16	0	---	---	3	405	12	8	387	20
Total	51	307	30	111	316	37	72	304	27	58	333	33	292	313	34

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix C11. Summary of RSD estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1993[a].

Year		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1955	Number sampled	118	45	10	0	0
Jul-	RSD	0.68	0.26	0.06	---	---
Sept	Standard Error	0.04	0.03	0.02	---	---
1956	Number sampled	204	31	4	0	0
Jun-	RSD	0.85	0.13	0.02	---	---
Aug	Standard Error	0.02	0.02	0.01	---	---
1970	Number sampled	802	42	0	0	0
Aug	RSD	0.95	0.05	---	---	---
	Standard Error	0.01	0.01	---	---	---
1972	Number sampled	163	9	0	0	0
Jun	RSD	0.95	0.05	---	---	---
	Standard Error	0.02	0.02	---	---	---
1972	Number sampled	120	2	0	0	0
Aug	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---
1975	Number sampled	636	12	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	<0.01	0.01	<0.01	---	---
1976	Number sampled	337	18	2	0	0
Jun	RSD	0.94	0.05	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1977	Number sampled	633	15	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1978	Number sampled	603	17	0	0	0
Jun	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1980	Number sampled	588	12	0	0	0
Jun	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---

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Year		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	112	102	37	0	0
May	RSD	0.45	0.41	0.15	---	---
	Standard Error	0.03	0.03	0.02	---	---
1982	Number sampled	314	11	0	0	0
Jun	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1984	Number sampled	443	39	0	0	0
Jun	RSD	0.92	0.08	---	---	---
	Standard Error	0.01	0.01	---	---	---
1985	Number sampled	217	210	80	0	0
May	RSD	0.43	0.41	0.16	---	---
	Standard Error	0.02	0.02	0.02	---	---
1985	Number sampled	169	35	1	0	0
Jun	RSD	0.82	0.17	0.01	---	---
	Standard Error	0.03	0.03	0.01	---	---
1985	Number sampled	322	60	0	0	0
Aug	RSD	0.84	0.16	---	---	---
	Standard Error	0.02	0.02	---	---	---
1986	Number sampled	167	151	28	0	0
May	RSD	0.48	0.44	0.08	---	---
	Standard Error	0.03	0.03	0.02	---	---
1986	Number sampled	560	80	6	0	0
Aug	RSD	0.87	0.12	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1987	Number sampled	58	128	130	1	0
May	RSD	0.18	0.40	0.41	<0.01	---
	Standard Error	0.02	0.03	0.03	<0.01	---
1987	Number sampled	290	66	2	0	0
Aug	RSD	0.81	0.18	0.01	---	---
	Standard Error	0.02	0.02	<0.01	---	---

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Year		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1988	Number sampled	1,213	725	73	0	0
Aug	RSD	0.60	0.36	0.04	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1989	Number sampled	1,239	515	62	0	0
Aug	Sampled RSD	0.68	0.28	0.03	---	---
	Adjusted RSD[c]	0.78	0.20	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---
1990	Number sampled	1,234	244	46	0	0
Aug	Sampled RSD	0.81	0.16	0.03	---	---
	Adjusted RSD[c]	0.84	0.14	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---
1991	Number sampled	686	90	11	0	0
Aug	Sampled RSD	0.87	0.12	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1992	Number sampled	454	97	11	0	0
Aug	Sampled RSD	0.81	0.17	0.02	---	---
	Standard Error	0.02	0.02	0.01	---	---
1993	Number sampled	809	71	9	0	0
Aug	Sampled RSD	0.91	0.08	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---

[a] Data Sources: 1955-1956 (Warner 1957); 1970 and 1972 (Tack 1971; 1973); June 1975-1982: (Peckham 1976; 1977; 1978; 1979; 1983); 1984 (Ridder 1985); May 1982, 1985, 1986, May 1987, (office files); August 1987 (Clark and Ridder 1988); 1988 (Ridder 1989); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (this report).

[b] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984): stock (150 -269 mm FL); quality (270 -339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

[c] RSD adjusted due to bias in length selectivity of the electrofishing boat.

[d] Standard error of the adjusted RSD.

Appendix C12. Summary of RSD estimates for adult Arctic grayling ($\geq$ 150 mm FL) in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

Year		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	17	99	37	0	0
	RSD	0.11	0.65	0.24	---	---
	Standard Error	0.03	0.04	0.04	---	---
1985	Number sampled	20	141	80	0	0
	RSD	0.08	0.59	0.33	---	---
	Standard Error	0.02	0.02	0.03	---	---
1986	Number sampled	8	109	24	0	0
	RSD	0.06	0.77	0.17	---	---
	Standard Error	0.02	0.04	0.03	---	---
1987	Number sampled	1	108	130	1	0
	RSD	<0.01	0.45	0.54	<0.01	---
	Standard Error	<0.01	0.03	0.03	<0.01	---
Total	Number sampled	46	457	271	1	0
	RSD	0.06	0.59	0.35	<0.01	---
	Standard Error	0.01	0.02	0.02	<0.01	---

[a] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

Appendix C13. Summary of RSD indices for adult Arctic grayling (≥ 150 mm FL) by sex in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Males:					
	Number sampled	10	51	30	0	0
	RSD	0.11	0.56	0.33	---	---
	Standard Error	0.03	0.05	0.05	---	---
1982	Females:					
	Number sampled	7	48	7	0	0
	RSD	0.11	0.77	0.11	---	---
	Standard Error	0.04	0.05	0.04	---	---
1985	Males:					
	Number sampled	4	39	44	0	0
	RSD	0.05	0.45	0.51	---	---
	Standard Error	0.02	0.05	0.05	---	---
1985	Females:					
	Number sampled	16	102	36	0	0
	RSD	0.10	0.66	0.23	---	---
	Standard Error	0.03	0.04	0.03	---	---
1986	Males:					
	Number sampled	2	56	20	0	0
	RSD	0.03	0.72	0.26	---	---
	Standard Error	0.02	0.05	0.05	---	---
1986	Females:					
	Number sampled	7	66	8	0	0
	RSD	0.09	0.82	0.10	---	---
	Standard Error	0.03	0.04	0.03	---	---
1987	Males:					
	Number sampled	1	68	110	1	0
	RSD	0.01	0.38	0.61	0.01	---
	Standard Error	0.01	0.04	0.04	0.01	---
1987	Females:					
	Number sampled	0	40	20	0	0
	RSD	---	0.67	0.33	---	---
	Standard Error	---	0.06	0.06	---	---

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	RSD Category				
	Stock	Quality	Preferred	Memorable	Trophy
Total Males:					
Number sampled	17	214	204	1	0
RSD	0.04	0.49	0.47	<0.01	---
Standard Error	0.01	0.02	0.02	<0.01	---
Total Females:					
Number sampled	30	256	71	0	0
RSD	0.08	0.72	0.20	---	---
Standard Error	0.02	0.02	0.02	---	---

[a] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

Appendix C14. Arctic grayling abundance, harvest, and exploitation estimates for the Goodpaster River, 1972 through 1993.

		Abundance[a]			Exploitation[b]	
Year	Month	0-53km	0-152km	Harvest	0-53 km	0-152 km
1972	JUNE	10,017	20,034	ND[c]	---	---
1973	JUNE	25,440	44,955	2,236	0.09	0.05
1974	JUNE	10,649	27,441	ND	---	---
1975	JUNE	25,166	50,332	ND	---	---
1976	JUNE	18,654	37,307	ND	---	---
1977	JUNE	19,999	39,998	ND	---	---
1978	JUNE	25,054	50,108	ND	---	---
1979	JUNE	ND	ND	ND	---	---
1980	JUNE	25,574	51,149	ND	---	---
1981	JUNE	ND	ND	ND	---	---
1982	JUNE	8,616	17,232	ND	---	---
1983	JUNE	ND	ND	3,021	---	---
1984	JUNE	18,656	37,312	1,194	0.06	0.03
1985	AUGUST	19,292	38,584	2,757	0.13[d]	0.07[d]
1986	AUGUST	16,165	32,330	1,508	0.09[d]	0.05[d]
1987	AUGUST	7,102	14,204	1,702	0.19[d]	0.11[d]
1988	AUGUST	8,374	16,748	1,273	0.13[d]	0.07[d]
1989	AUGUST	8,033	16,066	1,964	0.20[d]	0.11[d]
1990	AUGUST	7,113	14,226	760	0.10[d]	0.05[d]
1991	AUGUST	7,836	15,672	636	0.08[d]	0.04[d]
1992	AUGUST	6,886	15,304	766	0.10[d]	0.05[d]
1993	AUGUST	10,841	21,682	ND	---	---
Average		14,923	29,860	1,705	0.10[d]	0.05[d]

[a] Abundance in the lower 53 km for 1972 and 1975 through 1988 was extrapolated from fish per km estimates (Appendix B1). Abundance for 0 - 152 km for the same years is twice the estimate for the lower 53 km based on the average ratio between the sections estimated in 1973 and 1974 (Appendix B1).

[b] Exploitation rate is harvest divided by abundance.

[c] ND = no data.

[d] Harvests were added to abundance estimates to give an approximation of abundance at start of season prior to calculating exploitation rates.

APPENDIX D

Equations and Statistical Methodology

Appendix D1. Methodology to compensate for bias due to unequal catchability by river section.

Result of χ^2 test[a]	Inspection of fish movement[b]
Case I[c]	
Fail to reject H_o	No movement between sections
Inferred cause: There is no differential capture probability by river section or marked fish completely mixed with unmarked fish within each river section.	
Case II[d]	
Fail to reject H_o	Movement between sections
Inferred cause: There is no differential capture probability by river section or marked fish completely mixed with unmarked fish across river sections.	
Case III[e]	
Reject H_o	No movement between sections
Inferred cause: There is differential capture probability by river section or marked fish did not mix completely with unmarked fish within at least one river section.	
Case IV[f]	
Reject H_o	Movement between sections
Inferred cause: There is differential capture probability by river section or marked fish did not mix completely with unmarked fish across river sections.	

a The chi-squared test compares the frequency of marked fish recaptured during the second event in each river section with the frequency of unmarked fish examined in the second event in each river section. Ho for this test is: capture probability of marked fish in the second event is the same in all river sections.

b Inspection of fish movement is a visual comparison of the frequency of marked fish recaptured in the second event that moved from one river section to another with the frequency of unmarked fish examined in the second event in each river section.

c Case I: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator.

d Case II: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator and calculate one unstratified abundance estimate using the "movement" (Evenson 1988) estimator. If estimates are dissimilar, discard the Bailey estimate and use the movement estimate as the estimate of abundance. If estimates are similar, discard the movement estimate and use the Bailey estimate as the estimate of abundance.

e Case III: Completely stratify the experiment by river section, calculate abundance estimates for each using the Bailey (1951, 1952) estimator, and sum abundance estimates.

f Case IV: Completely stratify the experiment by river section. Calculate abundance estimates for each using the Bailey (1951, 1952) estimator and sum estimates. If movement out of the sample area is neither probable nor possible, calculate abundance with the partially stratified model of Darroch (1961) and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the Darroch estimate as the estimate of abundance. If estimates are similar, discard the estimate with the largest variance. If movement out of the sample area is probable, calculate abundance with the movement (Evenson 1988) estimator and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the movement estimate as the estimate of abundance (note: this estimate will be biased). If estimates are similar, discard the movement estimate and proceed as if movement were neither probable nor possible.

Appendix D2. Methodology to compensate for bias due to gear selectivity by means of statistical inference.

Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	
Fail to reject H_0	Fail to reject H_0
Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]	
Fail to reject H_0	Reject H_0
Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III[e]	
Reject H_0	Fail to reject H_0
Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]	
Reject H_0	Reject H_0
Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix D3. Equations used to estimate abundance and variance.

Bailey (1951,1952) estimator and variance

$$\hat{N} = \frac{M\,(C + 1)}{(R + 1)}, \text{ and} \tag{D3.1}$$

$$\hat{V}[\hat{N}] = \frac{M^2\,(C + 1)\,(C - R)}{(R + 1)^2(R + 2)} \tag{D3.2}$$

where: M = the number of fish marked and released alive during the first sample;

C = the number of fish examined for marks during the second sample;

R = the number of recaptured during the second sample;

$\hat{N}$ = estimated abundance of fish during the first sample; and,

$\hat{V}[N]$ = estimated variance of N.

Movement estimator of Evenson (1988)

$$\hat{N} = \frac{[\, M_1(1-\hat{\theta}_d) + M_2 + M_3(1-\hat{\theta}_u)\,]\,[C + 1]}{R_{..} + 1} \tag{D3.3}$$

The probabilities of movements are estimated by:

$$\hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2.}(M_3 + M_2)}, \text{ and} \tag{D3.4}$$

$$\hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2.}(M_1 + M_2)} \tag{D3.5}$$

where:

M_x = the number of fish marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream sections, respectively);

$R_{..}$ = the number of fish recaptured during the second event;

θ_z = the probability that a fish will move out of an area in the z direction (upstream or downstream);

C = the catch made during the second event; and,

N = the abundance of fish in all sections at the start of the second event.

R_{xy} = the number of fish that were marked in section x during the first event and were recaptured in section y during the second event; and,

$R_{2.}$ = the number of fish that were marked in the midstream section during the first event and were recaptured during the second event.

Appendix D4. Methods to compensate for bias in age and size compositions due to differential capture probability by size of fish or river section.

No adjustment needed

$$\hat{p}_k = \frac{x_k}{n} \tag{D4.1}$$

$$\hat{V}[p_k] = \frac{p_k\,(1 - p_k)}{n - 1} \tag{D4.2}$$

where: $\hat{p}_k$ = the proportion of fish that are age or size k;
x_k = the number of fish sampled that are age or size k;
n = the number of fish sampled that were aged or measured; and,
$\hat{V}[p_k]$ = the variance of the proportion.

Adjustment for differential capture probability by river stratum

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{D4.3}$$

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} (\hat{N}_i/\hat{N})^2\, \hat{V}[\hat{p}_{ik}] \tag{D4.4}$$

where: $\hat{p}_k$ = the average weighted proportion of fish in the entire area or that were age or size k;
$\hat{N}_i$ = the abundance of Arctic grayling in stratum i;
$\hat{N}$ = total abundance; and,
$\hat{p}_{ik}$ = the proportion of fish in stratum i that were age or size k.

APPENDIX E

Data File Listing

Appendix E1. Data files used to estimate parameters of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers, 1993.

Data file[a]	Description
U005ALA3.DTA	Population and marking data for Arctic grayling captured during the first marking event at the Salcha River, 7 through 8 June 1993.
U005BLA3.DTA	Population and marking data for Arctic grayling captured during the second marking event at the Salcha River, 9 through 10 June 1993.
U005CLA3.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Salcha River, 14 through 17 June 1993.
U004ALC3.DTA	Population and marking data for Arctic grayling captured during the marking event at the Middle Chatanika River, 16 through 19 August 1993.
U004ALD3.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Middle Chatanika River, 23 through 26 August 1993.
U0080LA3.DTA	Population and marking data for Arctic grayling captured during the marking event at the Goodpaster River, 3 through 5 August 1993.
U0080LB3.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Goodpaster River, 10 through 12 August 1993.

[a] Data files have been archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.